THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

The One Hundred and Seventeenth General Meeting of the Institution of Petroleum Technologists was held at the Royal Society of Arts, John Street, Adelphi, London, W.C., on Tuesday evening, February 12th, 1929, Mr. Alexander Duckham (in the absence of the President) occupying the chair.

The Chairman, at the opening of the meeting, expressed the regret of the President that he was unable to occupy the Chair that evening.

Election of New President.

The Chairman said it afforded him the greatest pleasure to announce that Dr. A. E. Dunstan had been elected President for the ensuing year. He would have liked to have had the privilege of expressing an appreciation of Dr. Dunstan, but he was told that it would be out of order on the present occasion, and he was therefore prevented from doing so.

The Secretary announced that the following gentlemen had been elected :—

Members.—Harm Leopold Buning, Macfarlane Douglas Gordon Campbell, John Willis Elder, Warren Fred Faragher, Silas Frederick Shaw.

Transference to Member.—William Herbert Fordham, Frederic A. Hessel.

Associate Members.—Geoffrey Hext Sutherland Bushnell, Robert Gourlay, William Wallace Pearce, William Prentice Robertson, Robert Frederick Strickland-Constable.

Transference to Associate Member.—Geoffrey Cotton.

Student.—Frederick Robert Symonds.

The Secretary announced that the General Meeting on March 12th would be held at the Royal Society of Arts at 5.30 p.m., but that the Annual General Meeting on March 19th would be held at the offices of the Institution, Aldine House, at 5.45 p.m., instead of as announced on the card at the Royal Society of Arts at 8.30 p.m.

In the absence of the authors the following paper was read by Mr. J. Romanes :—

The Chemical Investigation of Trinidad Well Waters and its Geological and Economical Significance.

By J. S. PARKER, M.A., B.Sc. (Member), and C. A. P. SOUTHWELL, M.C., B.Sc., F.G.S. (Member).

INTRODUCTION.

The Trinidad well water question has occupied the attention of Petroleum Technologists since the early development of the oil-bearing zones. Prior to the year 1921, water-bearing formations were occasionally reported, and a few samples of well waters were analysed. These results are available, but no attempt seems to have been made, up to this time, to understand the significance of the results and to lay down a programme for the continuance of the investigation. Since 1921 an organised chemical study of the well waters has been undertaken.

The slow progress in this problem has been due to its many difficulties. Had the chemical characteristics of the well waters from the various horizons shown consistent distinctive features, these would have been recognised in the early stages of the investigation and the problem would have progressed rapidly. When the investigation first commenced, the Chemist and the Exploitation Geologist were faced with uncertain data due to lack of knowledge regarding the source of the sample and the exact geological horizon from which it was obtained. Progress in knowledge regarding the sub-surface conditions has been rapid of late years owing to the more general use of coring, so that it is now possible to correlate the chemical study of the problem with the geological data.

The chemical investigation of the characteristics of salt water accumulations within the series of strata from which oil is produced is advisable for the following reasons:—

1. Estimates may be made of the probable horizons at which to expect salt water-bearing strata, and mechanical programmes may be arranged accordingly.

2. In areas where zonal fossils or typical rocks are not available, the correlation of salt waters may afford additional evidence in the interpretation of the sub-surface structure.

3. The source of a salt water, which may subsequently break into a well, may be determined.

4. The distribution of similar type waters may be determined as an aid to the elucidation of the extent and trend of porous sand bodies so that a more accurate idea may be obtained of the sub-surface conditions from an oil accumulation standpoint.

The extent of the scientific study undertaken on this problem during the exploitation of any structure is governed by a balance between the probable value of the work and the expenditure entailed. After considering the problem from a theoretical point of view it is necessary to reduce it to practical proportions, and a decision has to be made as to the expenditure justified in obtaining the samples of well waters required for the chemical research.

Under ideal conditions of scientific operating it is necessary to identify all salt water-bearing formations penetrated in the early stages of drilling up a structure and to obtain accurate samples of these waters for chemical investigation. In the earlier stages of development the Operator is very much against the delays caused by the special operations necessitated if he has to obtain accurate samples of the salt waters. Accidents, with the possibility of lengthy fishing jobs, may result through no fault of the Operator. In the past, the chemical investigation of the well waters has been considered in many quarters to be more of academic interest than of economic value and has usually been neglected in the early stages of development.

If the sample submitted to the Chemist truly represents the water in the underground reservoir from which it is derived, the work of the Chemist, assuming that the analytical results are sufficiently informative, would be purely a question of providing precise data for the Exploitation Geologist to interpret. Unfortunately the conditions under which the well samples are taken are in many cases far from satisfactory, due to circumstances not under the control of the person taking the sample, so that the precise data which the Chemist provides must be considered in conjunction with other factors, and a co-operative study is essential.

The problems on one field were too limited to give a true conception of the well water question in Trinidad, and it was necessary to attack the problem as a whole. This Report has been compiled to place on record the complete results to date of the chemical work undertaken on Trinidad well waters, considered in conjunction with the geological knowledge as a guide and a basis for future development.

Geological.

Before considering the chemical relationship of the salt-water accumulations within the oil-producing series of Trinidad, it is necessary to investigate the conditions of sedimentation.

The sediments of Miocene Age, from which commercial oil is produced, have been transported and deposited by a river system flowing from the mainland of South America in a north-easterly direction.

This period of deposition has provided a series of sediments of between 5000 and 7000 ft. thick, consisting of clays, silts, sandy clays, and sands of every gradation, the result of estuarine and close-to-shore-line deposition. This thickness is approximate. Its exact determination is not possible owing to the absence of regular successions at the surface and the difficulty of determining the structural conditions due to the absence of horizon markers. It is only possible to generalise on the conditions of sedimentation, despite the fact that there is a vast amount of geological data available regarding the sub-surface conditions in the various fields.

It was previously assumed, from the correlation of drillers' logs and the interpretation of the "drillings," that the sandy deposits had great lateral variation and hence differed in porosity from well to well within the same zone. This has lately been proved by coring.

The general geological conditions of the sub-surface reservoirs from which the salt water samples have been obtained are given as follows:—

1. Vertical variation: the producing series being made up of alternations of clays, silts and fine and coarse sands.

2. Lateral variation of the sandy sediments of the oil series within a silty or clayey matrix has caused the porous parts within which the accumulation of fluids is possible to be of an irregular type.

3. Minor irregularities, the details of which it is impossible to define precisely, as the expenditure required to obtain sufficient data is not warranted. We refer to minor faulting, especially within the core of the structures, which may have brought sandy zones from different stratigraphical levels into contact and to local unconformities. These minor complications take place within small areas and are therefore too detailed for satisfactory geological interpretation.

In considering the segregation of oils and salt waters into the porous sand bodies of these Miocene sediments, it is necessary to appreciate the fact that this has not been brought about by hydrostatic pressure under regular conditions of sedimentation, but by earth movement whereby differences in pressure have been created within the strata. It is assumed for the purpose of this well water study that the oil has been formed in the foraminiferal sediments, and has been forced from these mother rocks along the bedding and joint planes into the porous parts. There is no doubt that the original arrangement of the waters and oils during early folding has been complicated by subsequent intensive movement. An illustration of the sub-surface condition is to be found in Fig. 1 accompanying this Report.

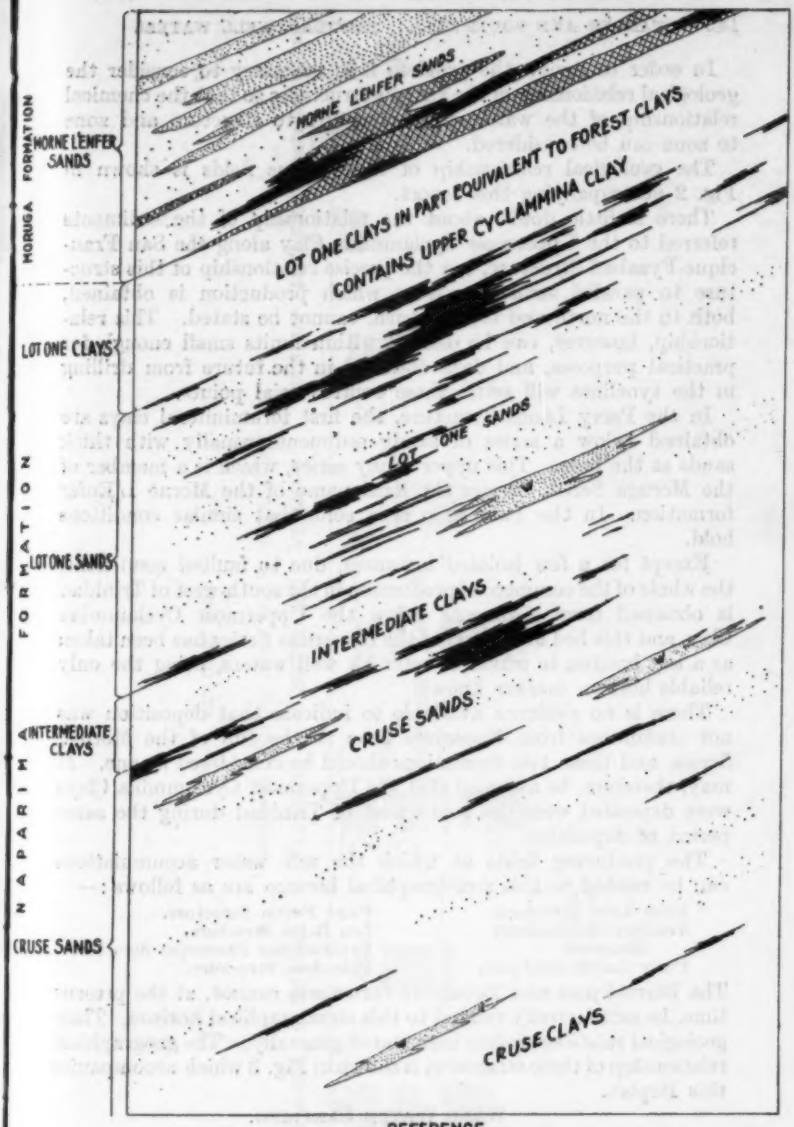


FIG. 1.

SECTION THROUGH OIL-PRODUCING SERIES OF SOUTH-WESTERN TRINIDAD SHOWING LATERAL VARIATION OF OIL AND SALT WATER ACCUMULATION BASED ON CORE EVIDENCE.

In order to review the problem it is necessary to consider the geological relationship of the various structures so that the chemical relationship of the waters from structure to structure and zone to zone can be considered.

The geological relationship of the various fields is shown in Fig. 2 accompanying this report.

There is little doubt about the relationship of the sediments referred to the Uppermost Cyclammina Clay along the San Francique-Fyzabad Structure, but the precise relationship of this structure to parallel structures from which production is obtained, both to the north and to the south, cannot be stated. This relationship, however, can be defined within limits small enough for practical purposes, and data obtained in the future from drilling in the synclines will settle these controversial points.

In the Parry Lands Structure, the first foraminiferal clays are obtained below a series of sandy sediments usually with thick sands at the base. This upper sandy series, which is a member of the Moruga Series, carries the local name of the Morne L'Enfer formation. In the Palo Seco area somewhat similar conditions hold.

Except for a few isolated instances, due to faulted conditions, the whole of the commercial production in the south-west of Trinidad is obtained from sediments below the Uppermost Cyclammina Clay, and this bed at the top of the Naparima Series has been taken as a key horizon to which to refer all well waters, being the only reliable horizon marker known.

There is no evidence available to indicate that deposition was not continuous from Naparima time to the top of the Moruga Series, and these two formations should be considered as one. It may, therefore, be assumed that the Uppermost Cyclammina Clays were deposited over the south-west of Trinidad during the same period of deposition.

The producing fields at which the salt water accumulations can be related to this stratigraphical horizon are as follows:—

Pitch Lake Structure.	Point Fortin Structure.
Vessigny-Boodoosingh Structure.	Los Bajos Structure.
Parry Lands Structure.	Fyzabad-San Francique Structure.
	Palo Seco Structure.

The Barrackpore and Tabaquite Structures cannot, at the present time, be satisfactorily related to this stratigraphical horizon. Their geological relationship has been stated generally. The geographical relationship of these structures is shown in Fig. 3 which accompanies this Report.

Well Water Sampling.

The whole value of well water analytical work depends on the taking of a sample which accurately represents the water in the

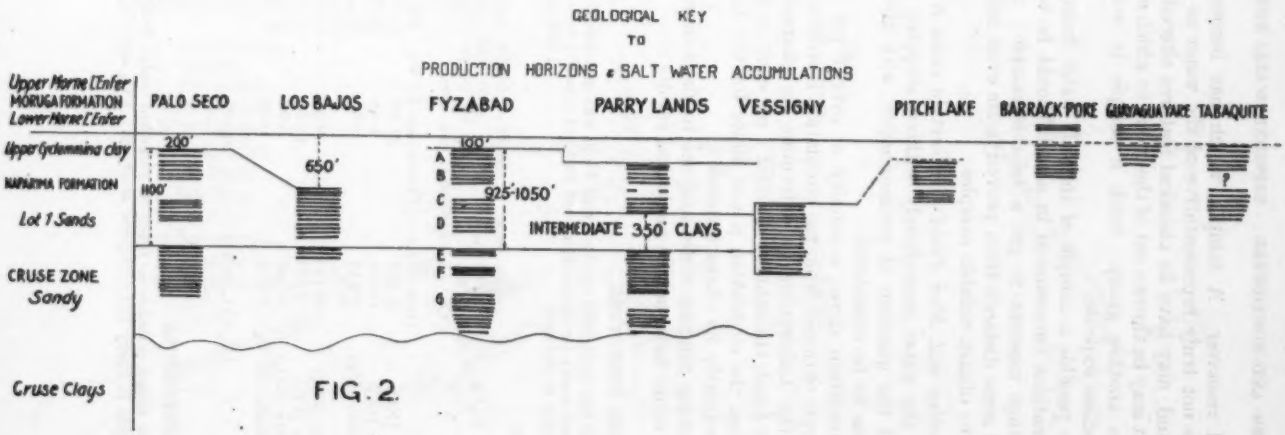

GEOLOGICAL KEY
TO
PRODUCTION HORIZONS & SALT WATER ACCUMULATIONS
Upper Morne L'Enfer
MORUGA FORMATION
Lower Morne L'Enfer
PALO SECO
LOS BAJOS
FYZABAD
PARRY LANDS
VESSIGNY
PITCH LAKE
BARRACK PORE
GUAYAGUAYARE
TABAQUITE
Upper Cretaceous clay
MAYARO FORMATION
Lot 1 Sands
CRUSE ZONE
Sandy
Cruse Clays
200'
100'
650'
100'
A
B
C
D
925-1050'
INTERMEDIATE 350' CLAYS
E
F
G

FIG. 2.

underground reservoir. A sample, which has become contaminated and is not truly representative of the water as it exists in the water sand, may have its chemical features altered to such an extent that it may be thrown out of the group to which it chemically belongs into another group. Such a sample is worthless and involves needless expense.

Whenever possible a sample of the salt water from the water-bearing formations encountered in a well should be taken at the most opportune moment to get a reliable sample; and at new wells drilled some distance from proved lands even more attention is required to obtain reliable samples.

Contamination with Mud Fluid.—In certain cases it is desirable to mud off the water immediately without stopping to obtain a sample, and the question of contamination with the circulating mud fluid has to be considered.

If the circulation shows a salinity of over 1 per cent. NaCl, a water sample obtained from the circulation is sufficiently concentrated for the Laboratory to determine its characteristics. If, on the other hand, the salinity is under 1 per cent., a water sample obtained from the circulation is too dilute for the Laboratory to evaluate accurately its characteristics.

The following samples were analyses to determine what effect mud fluids could have on the analytical results :—

Parry Lands Structure.

A sample of the mud fluid used on this Field was analysed. The mud was in a mixed state ready for circulation, but had not actually been in circulation.

Total Solids in Solution .. .. 1·522 gms. per litre.

Constituents :

Silica ..	.. 0·010 gms.	MgO –	0·068	gms.	per litre.
$Fe_2O_3 + Al_2O_3$	.. 0·004 ,,	Cl_2 –	0·0688	,,	,,
CaO ..	.. 0·034 ,,	SO_3 –	0·129	,,	,,

CO_2 – 0·146 gms. per litre.

	Gms./litre.	Percentage by wt.	Re-acting Value %	
Sodium (Na)	.. 0·509	31·46	41·4	
Calcium (Ca)	.. 0·024	1·48	2·3	
Magnesium (Mg)	.. 0·041	2·53	6·3	
				50·0
Sulphate (SO_4)	.. 0·155	9·58	6·0	
Chloride (Cl_2)	.. 0·688	42·53	36·3	
Carbonate (CO_3)	.. 0·049	3·03	3·0	
Bicarbonate (HCO_3)	0·152	9·39	4·7	
				50·0
	$Cl_2/CO_2 = 4·7$	100·00		

Fyzabad Structure.

It was not found possible to filter off sufficient water from the samples of the mud fluids to carry out complete analyses; CO_2 and Cl_2 only were esti-

FIG.3.
SKETCH MAP
SHEWING THE
PRODUCING STRUCTURES OF TRINIDAD
Scale: 1:300,000
1 Pitch Lake Area
2 Vessigny "
3 Parry Lands "
4 Point Fortin "
5 Fyzabad-West "
6 Fyzabad-East "
7 Los Bajos "
8 Palo Seco "
9 Cedros "
10 Barrackpore "
11 Tabaquite "
12 Guayaguayare "
RIO CLARO
RIO CLARO-GUAYAGUAYARE ROAD
MORUGA ROAD
PRINCES TOWN
PENAL-ROCK ROAD
SAN FERNANDO
SOUTHERN MAIN ROAD
SOUTHERN
SAN FERNANDO
SOUTHERN MAIN ROAD

mated. The depths stated are the depths at which the mud was being circulated. The muds made by drilling on this structure have a very high viscosity and are of a colloidal nature.

	CO_2	Cl	Cl_2/CO_2
	gms./litre.		
1. 300 ft. drilling above the Forest Clay; should not have any contamination with salt water ..	0·776 ..	0·941 ..	1·2
2. 495 ft. Drilling above the Forest Clay: should not have any contamination with salt water ..	0·344 ..	0·796 ..	2·3
3. Drilling about 1100 ft. below the Forest Clay	0·435 ..	0·579 ..	1·3
4. Drilling at 1800 ft. stratigraphically below Forest Clay. Salinity tests show that salt water has access. Salt water sands passed higher up the hole	0·367 ..	1·376 ..	3·8

PALO SECO STRUCTURE.

Owing to the small quantity of the water filtered off from the samples submitted CO_2 and Cl_2 only were estimated.

	CO_2	Cl_2	Cl_2/CO_2
	gms./litre.		
1. 839 ft.	0·319 ..	1·158 ..	3·6
2. 1165 ft.	0·412 ..	0·507 ..	1·2
3. 1175 ft.	0·348 ..	0·434 ..	1·2

To arrive at some idea of the Carbonate plus Bicarbonate percentages in these samples the proportion Cl_2/CO_2 has been worked out for each. Comparing the 4·7 of the Parry Lands Structure which has about 12 per cent. Carbonate plus Bicarbonate with the 1·2 to 3·8 of the Fyzabad and Palo Seco Structures, it will be seen that the water in the mud fluid used on these latter structures has a much higher Carbonate plus Bicarbonate percentage.

It is probable that the 1·2 represents about 40 per cent. Carbonate plus Bicarbonate. With this high Carbonate plus Bicarbonate percentage it is probable that the calcium and magnesium percentages are considerably lower than those obtained for the Parry Lands mud fluid water.

The Parry Lands mud fluid had not been in circulation, and one can draw no contamination data from it. It is certain that on circulation it would approximate to the other mud fluids both in consistency and in Carbonate plus Bicarbonate percentage.

Contamination with mud fluid will result in general in a lower concentration and a higher Carbonate plus Bicarbonate percentage. The lower the Carbonate plus Bicarbonate percentage in the original water the higher will be the contaminating effect.

Reliability of Samples.—The reliability of the samples analysed in this investigation vary from a good sample from a known geological horizon to a sample of such a doubtful nature that it is not

even known from which major zone it is derived. It has, therefore, been decided to sub-divide all the results into four groups in accordance with their reliability, the groups being designated A, B, C and D (see page 8).

Chemical Investigation.

Methods of Analysis.—Owing to the necessity of curtailing the length of this Paper, the details of the methods of analysis and the method of calculating the results have been omitted. It is, however, advisable to consider the factors which influence the adoption of these methods. The Chemist and the Exploitation Geologist control the scientific side of the well water question from sampling to the final report. There is a tendency for them to add to and lengthen the analytical work. On the other hand, the Field Staff want to know where the water has come from, and, to be of any use, they require to know this quickly. In drawing up a system of analytical tests it is advisable to strike a mean between the requirements of theory and the requirements of practical utility.

The most satisfactory tests are those which are simple, quick and cheap, capable of being carried out by the Field Staff with a minimum of apparatus. Tests such as these, however, are only possible when the correlating features of the well waters are known. Until this stage is reached it is necessary to examine fully the various constituents.

The analytical work at the outset generally falls on the Refinery Laboratory, which is never in a position to devote much time to work of this nature. The original tests should therefore be complete, and, at the same time, simple and quick. This can be secured by organising the analytical work, limiting the degree of accuracy required, and eliminating estimations which are of no comparative value.

The Degree of Accuracy Required.—There is a general tendency to go to extremes over the question of analytical accuracy. This will happen when several laboratories are engaged on the analytical work, or when complete co-ordination between the geologist and the chemist does not exist. When one considers the various sources of possible error it will be seen that the accidental error of the laboratory is infinitesimal when compared with the errors of sampling. Extreme analytical accuracy is therefore unnecessary. The analytical methods adopted in Trinidad and the reporting of the constituents to one milligram per litre have proved to be sufficiently accurate to obtain definite correlations of the well waters.

The Comparative Value of the Various Estimations.—This cannot be foretold at the outset, when it is necessary to include all the standard constituent tests.

STANDARD CONSTITUENT TESTS.

Silica.	Calcium.	Sulphate.
Iron Oxide and Alumina.	Magnesium.	Carbonate.
Sodium and Potassium.	Chloride.	Bicarbonate.

To these should be added iodine, which has proved to have correlating value on several fields.

It will soon be noted which tests are of no value for purposes of comparison and these can be eliminated. As far as Trinidad well waters are concerned, silica, iron oxide and alumina estimations may safely be eliminated from the analytical work. Sulphate as a whole is of no value for correlating purposes, though it is of interest in several individual cases. It is doubtful whether the practical value of this constituent is sufficient to make it worth while retaining the estimation. Sodium, including potassium, can be calculated from the other constituents. Most pamphlets on the subject would discourage this. The whole value of the well water question depends on arriving at a simple series of tests which can be carried out on the field. The estimation of sodium is necessary for accurate work, but experience on Trinidad waters has shown that the calculation of sodium is sufficiently accurate for correlation purposes.

A value for sodium is necessary when the Palmer-Stabler system is used. Percentage by weight is equally valuable for correlation purposes, and in this case even a calculated value for sodium is unnecessary, as sufficient comparative accuracy can be obtained by estimating the constituents as a percentage of the total solids.

General Data.—The following table of solubilities has proved of value for considering the constituents of Trinidad well waters, and more especially for considering the changes which these constituents may undergo when the conditions under which they exist are altered.

	Solubility in parts per 100.	
	15° C.	100° C.
$CaCO_3$	0·002	—
$CaCl_2$	66	154
$CaCl_2$, 6 aq.	400	650
$CaSO_4$	0·20	0·17
$CaSO_4$, 2 aq.	0·24	0·22
$MgCO_3$	0·011	—
$MgCl_2$	54	73
$MgCl_2$, 6 aq.	167	367
$MgSO_4$	34	74
$MgSO_4$, 7 aq.	120	670
Na_2CO_3	16·5	45
Na_2CO_3, 10 aq.	93	540
$NaHCO_3$	8	decomposes.
NaCl	35	40
Na_2SO_4	13·5	43
Na_2SO_4, 10 aq.	40	322/30°

Calcium may exist as the bicarbonate in waters saturated with carbon dioxide. In this case the solubility is approximately thirty times higher than that given for calcium carbonate.

Detailed descriptions of tests evolved for well water analyses may be found in

1. "Methods of Making and Interpreting Oil Field Ground-Water Analysis." Lester C. Uren.
2. "Direct Titrometric Methods for Magnesium, Calcium and Sulphate Ions and their Application in Water Analysis." E. P. Schoch.
3. "Rapid Methods of Water Analysis." F. S. Tickell.

Tickell's pamphlet gives volumetric methods for determining sulphate and calcium plus magnesium.

Schoch's titrometric tests have been tried out on Trinidad well waters with the following results:—

The method is quick and fairly accurate, but requires considerable practice, as the standard blue end point is so faint as to be easily overshot. It is probable that the method was evolved for colourless waters containing small amounts of solids in solution. It is recommended in the text to boil down 800 to 1000 c.c. For Trinidad well waters 200 c.c. is quite sufficient. Care should be taken that the quantity of water does not require more than 20 c.c. of each reagent, otherwise the solution becomes too bulky to handle.

The method cannot be recommended for Trinidad well waters. The majority of these are strongly coloured with naphthenic salts or other organic matter and the colour becomes intensified on concentration. This colouration makes it extremely difficult to obtain the correct end point.

The pamphlets quoted above may be found in

1. California State Mining Bureau Bulletin. December, 1924.
2. Industrial and Engineering Chemistry. January, 1927.
3. Oilfield Engineering. May, 1927.

Factors Used in Calculation.

Conversion Factors:—

SO_4	to Ca	..	0·417	$Mg_2P_2O_7$	to Mg	..	0·218
Ca	to SO_4	..	2·397	SO_3	to SO_4	..	1·200
Ca	to Cl_2	..	1·770	CO_2	to CO_3	..	1·364
Mg	to Cl_2	..	2·916	CO_3	to HCO_3	..	1·386
HCO_3	to Na	..	0·377	HCO_3	to CO_3	..	0·984
SO_4	to Na	..	0·479	$BaSO_4$	to SO_3	..	0·343
CO_3	to HCO_3	..	1·017	CaO	to Ca	..	0·715
*Cl_2	to Na	..	0·649	MgO	to Mg	..	0·603
CO_2	to Na	..	0·767	$Mg_2P_2O_7$	to MgO	..	0·362

Allocation:—

SO_4 to Ca. Excess Ca to Cl_2.
Excess SO_4 to Na. Mg to Cl_2.
Excess Cl_2 to Na. CO_3, HCO_3 to Na.

* The chemical symbols used are in some cases not strictly correct, e.g., Cl_2 to Na, instead of Cl to Na. Symbols used in the "Methods Used in Recording the Results" have been retained throughout, so that there is no possibility of misconception.

Calculation of the Results.—The percentage by weight is calculated for Sodium (Na), Calcium (Ca), etc., by estimating the percentage grams per litre in the total grams per litre.

The reacting values in per cent. are calculated from the percentage by weight by multiplying by the corresponding factors and reducing to a percentage.

Reaction Co-efficients:—

Na	0·0435	SO_4	0·0208
Ca	0·0499	Cl_2	0·0282
Mg	0·0822	CO_3	0·0333
	HCO_3 ..	0·0164.	

Comparative Value of the Constituents.—All Trinidad well waters which have been analysed have contained bicarbonate or a mixture of bicarbonate and carbonate. The comparison of Trinidad waters is based mainly on these radicals.

The total of Calcium and Magnesium and the ratio Calcium/Magnesium are also of importance for purposes of comparison. These show marked variations in the waters on several of the Fields.

A simple test for Iodine, worked out by the Shell-Mex Central Laboratory, was taken into practice towards the later stages of the well water question in Trinidad. Results so far as they have gone would appear to indicate that the Iodine test is of distinct comparative value in dealing with these waters.

Standard Iodine Test.—A known volume of the water should be filtered and a quantity, if possible not less than 500 c.c. of the filtered water, should be evaporated on a water bath to approximately one-tenth of its volume. Most oil well waters at this concentration deposit calcium sulphate and calcium carbonate. The concentrated water is filtered and the filter paper washed with the smallest amount of distilled water.

The filtrate should represent approximately one-tenth of the volume of the original water. To each 50 c.c. of concentrate add 2·5 c.c. glacial acetic acid, the operation being carried out in a small separating funnel. After mixing thoroughly add 10 to 15 c.c. of hydrogen peroxide (20 vol.) and agitate the mixture. Finally add 20 c.c. of chloroform and agitate the mixture.

Since the liberation of the Iodine is a time reaction the mixture should be shaken vigorously at intervals, and, for preference, allowed to stand overnight, a few vigorous shakings being applied next morning.

The whole of the Iodine is taken up by the Chloroform, giving a red solution. The chloroform is separated into a suitable vessel.

The liquid should be washed with a further 10 c.c. of chloroform, which is added to the original chloroform. The Iodine is determined either

1. N/10 thiosulphate titration direct.
2. Colorimetrically against standard iodine-chloroform solutions.

The standard solutions are made by treating known weights of Potassium Iodide in solution with Acetic Acid, Peroxide and Chloroform as above.

The titration method has been used throughout on Trinidad Well Waters.

The majority of Trinidad well waters are coloured, the colour ranging from a pale yellow to a dark red brown. This would suggest a natural method of distinguishing the waters. It has not been possible to carry out sufficient research work on this question to enable a definite statement to be made on the comparative value of colour. There are, however, numerous instances of colour having definite value for correlation purposes, and the question is put forward so that Geologists and Chemists may follow it to its logical conclusion.

Colour is due to

1. Naphthenic Salts, or
2. Other Organic Compounds.

Naphthenic Salts are the most general. Trinidad Crude Oils are rich in naphthenic acids, and the presence of naphthenic salts in the well waters indicates contact, at some period, between the Well Water and the Crude Oil.

Though colour has been reported since the outset, the value of colour was not recognised until 1926, when a definite colour standard was set up against which all further well waters were compared.

Many of the waters have been produced, in one way or another, with the crude oil. Whether the colour of the water is due to the short period during which it has been in contact with the crude in the hole or whether it is essentially due to a long period of contact has not been definitely established. On the other hand water has been produced, flowing, from a grey water sand with no trace of oil, and this water has had a definite naphthenic colour.

The naphthenic colour is either pink or a colour ranging from yellow to red brown. The pink gradually changes to the yellow-red brown, which is a similar action to that of the naphthenic acids in the distillates derived from the crude oil. In a certain group of waters a practically colourless water changes to a brown in a period of time varying from 24 hours to two or three days.

By placing a crude oil film on top of one of these waters and allowing it to stand in the light it was proved that the colour reversion was due to oxidation.

The following results bearing on the naphthenic salt question have been kindly furnished by the Trinidad Leaseholds Laboratory:

"Contents in parts per million of the Salts of Petroleum Acids present in various salt waters from oil wells:—

		Parts per Million.	Remarks.
Main and Bernstein Fields.			
Well No.	A	1100 ..	Darkening rapidly.
,,	B	857 ..	—
,,	C	1753 ..	Darkening rapidly.
,,	D	2318 ..	Darkening rapidly.
,,	E	1380 ..	Darkening rapidly.
,,	F	739 ..	Darkening gradually.
,,	G	1469 ..	Darkening rapidly.
Barrackpore.			
Well No.	A	250 ..	No discolouration.
,,	B	469 ..	Darkened slightly.
,,	C	108 ..	No darkening.
,,	D	241 ..	No darkening appreciable.
Guayaguayare.			
Well No.	A	158 }	Inappreciable colour development.
,,	B	232 }	
,,	C	850 ..	Darkened gradually.

Waters containing appreciable quantities of the petroleum acids are usually found to possess some degree of colour, even when fresh. A faint yellowish brown tint is usual.

These waters have been observed invariably to deepen in colour on exposure to light and air, colour development being most rapid in the cases of waters containing the largest quantities of petroleum acids.

Some waters have attained a deep bright yellow colour, though generally a reddish brown results.

The acids when freshly precipitated are light brown in colour and gummy. They change to harder, black, asphaltic-like substances on exposure to air. When fresh it is uncertain whether the free acids are heavier than water, though they rapidly oxidise, and after boiling for a while they sink to the bottom of the aqueous solution from which they were separated. It has been observed that samples of water kept under a layer of oil and exposed to light develop colour very much less readily than samples exposed to light and air."

Colour is intensified on concentration. Because of this colour it is practically impossible to apply rapid volumetric tests for calcium, magnesium and sulphate to Trinidad well waters.

The final depth of colour would apparently be directly proportional to the percentage of naphthenic salts present, in solution though this has not been actually proved.

This colour question has been dealt with fully, as it has all the possibilities of providing a very simple method of comparison. To ensure comparative results it will be necessary to note the colour immediately the water has been taken from the well or after the colour has gone to its full limit and shows no further variation.

It will also be necessary to compare the water colour with a standard made up from stable compounds or to read off the colour on a Lovibond Tintometer. The question is worthy of further research work.

Odour is of no value. Sulphuretted Hydrogen alone has been reported, and this only in one water sample.

Concentration has distinct value in checking the contamination of the well water sample, and is also of value in the correlation of the well waters.

Suggested Method of Routine Chemical Analysis of Trinidad Well Waters for Field Use.

As the identification features of the Trinidad well waters are known to be the Carbonate plus Bicarbonate, the chemical interpretation of these waters could be reduced to a single routine analysis.

Colour is a useful identification feature which can be readily noted on the field. It should not be used alone, but should be checked by the other chemical features of the water.

The specific gravity can be taken on the field and so long as care is taken to get the water to about 80° F. before taking the gravity a sufficiently accurate value can be obtained for the total solids in solution from Fig. 4 or by computation.

By a simple titration a value can be obtained for the carbonate and the bicarbonate. The [illegible]tage of these in the water can be estimated from the grams per litre figure for total solids obtained from Fig. 4.

By drawing a graph, using [illegible] concentration and Carbonate plus Bicarbonate features only, a rapid approximation to the type water can be obtained.

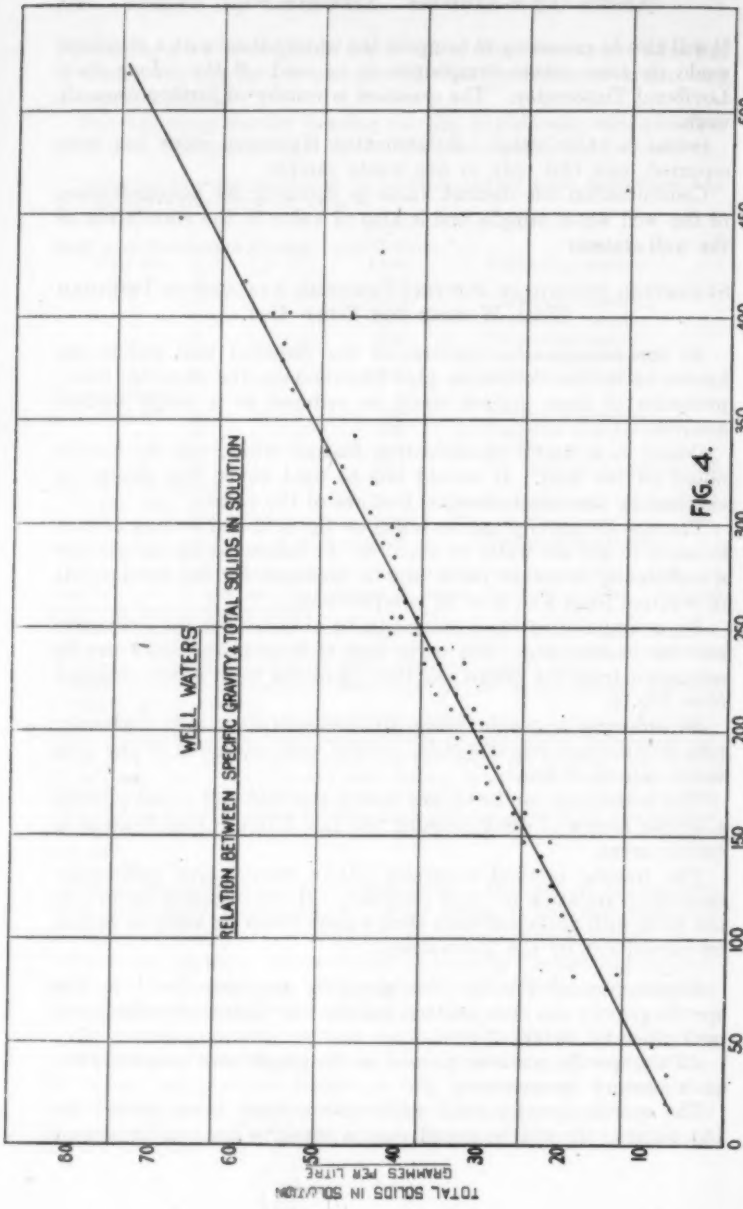
The Iodine test can be carried out on the field and would provide a simple means of distinguishing the Lot 1 from Cruse Waters in certain areas.

The routine method suggested above should give sufficiently accurate correlation for field purposes. If the chemical results do not fit in with geological data then a more complete analysis should be carried out by the Laboratory.

Explanation of Fig. 4.—For graphing purposes the 1 in the specific gravity has been omitted and the four figures after the point multiplied by 10,000.

All the specific gravities entered on the graph have been recorded at laboratory temperature.

The specific gravity/total solids points [illegible]been plotted for 150 waters. It will be noted that a [illegible]ne can be drawn


WELL WATERS
RELATION BETWEEN SPECIFIC GRAVITY & TOTAL SOLIDS IN SOLUTION
FIG. 4.
SPECIFIC GRAVITY
TOTAL SOLIDS IN SOLUTION
GRAMMES PER LITRE
0
50
100
150
200
250
300
350
400
450
500
10
20
30
40
50
60
70
80

through these points so that the points are either on the line or very close to it.

As the specific gravities have been reported at laboratory temperature (80° F.), the straight line cuts the total solids axis at 4 instead of passing through zero.

The graph shows that, for Trinidad well waters, the specific gravity is directly proportional to the total solids in solution.

The grams per litre of total solids may be obtained from the specific gravity of any Trinidad well water by reading the value off on the graph or they may be obtained by computation as follows :—

> Omit the 1 in the specific gravity. Multiply the four figures after the point by 10,000. Multiply this result by 0·1344, add on 4·0000 and call the resulting value grams per litre.

Methods of Recording Analytical Results.

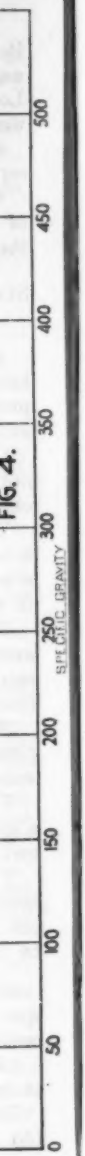
Numerical.—The three main systems of reporting well water analyses are :—

1. The Ionic System in which the constituents are reported in Ionic form as milligrams per litre or parts per million.
2. The Combination System in which the constituents are reported with the ions combined to give their hypothetical form of existence in the water ; in milligrams per litre or parts per million.
3. The Palmer System in which the constituents are reported according to their reaction values and their reaction properties in per cent.

The Ionic System is fundamentally sound as it records the actual results of chemical analyses and makes no attempt to group or combine these into hypothetical forms which may or may not exist in the water analysed. It is the system generally adopted by the chemist as it gives him a simple and accurate basis of comparison and enables him to arrive rapidly at a chemical interpretation of any constituent variation.

The Combination System is derived from the Ionic System and is sufficiently accurate for comparative purposes provided the ions are combined according to one standard method of allocation. Chemical analyses discover and give a value for the ions, sodium, calcium, magnesium, chloride, etc. The actual form in which these ions are present in the water, sodium chloride, calcium sulphate, etc., is a matter of conjecture. There are several equally probable methods of combining the ions and each method will

FIG. 4.



give a different result when calculated from the same Ionic values. It will thus be seen that one standard method of allocation is necessary.

The Combination System is of little value in well water work for the chief reason that it gives less information than the Ionic System, whilst at the same time involving further elaborate calculation.

The Palmer System sets up an arbitrary combination of the ions into what is termed primary salinity, secondary salinity, primary alkalinity and secondary alkalinity. The combinations are made according to a standard method and the final results are obtained in condensed form. The system was evolved by Stabler for industrial waters and adapted by Palmer to well waters. It is the system generally adopted by Geologists as it reduces the results to a condensed form and as it is standard. The main faults of the system are:—

1. That it is based on the Ionic System, that it involves a considerable amount of calculation from the Ionic System, and that the figures finally arrived at are less informative than the original figures.

2. The Palmer System actually makes use of two tables:
   (*a*) reacting values in per cent., and
   (*b*) reaction properties,
and is thus more involved than the Ionic System. The general tendency is to consider only the condensed form of the reaction properties. By doing so, one is merely considering symbols and loses all true conception of the chemical data.

3. Concentration is an important factor in well water work, and the Palmer System does not emphasise the point. Reistle would make much of this in his "Identification of Oil Field Waters," but it cannot be considered a major fault, as most geologists do consider concentration in conjunction with the Palmer System. It must be admitted, however, that the general tendency is to go for the reaction properties and forget all other features.

The Ionic System and the Palmer System are illustrated in this Report.

Graphical.—A satisfactory graphical method of recording the chemical characteristics of well waters should conform to the following:—

1. It should show the characteristics required to differentiate the water.

2. It should show the concentration of the sample.

3. It should be simple to plot and should be plotted without colours on tracing paper in black ink, so that duplicate copies can be made.

Palmer System.—The grouping of the waters has been carried out essentially from the reaction properties, and the primary alkalinity is the feature on which the grouping has been based.

The reaction properties are shown in graphical form. They have been plotted, as percentages, on millimetre square paper, in the order: (1) Primary Salinity; (2) Secondary Salinity; (3) Primary Alkalinity; (4) Secondary Alkalinity. On the horizontal scale 5 mms. interval is kept between (1), (2), (3) and (4). On the vertical scale the values of (1), (2), (3) and (4) have been plotted as percentages using 50 mms. to represent 100 per cent. This scale is the most compact.

Parker System.—This System is based on the concentration and on the percentage by weight of the constituents in the water analysed, and is a combination of both. Fig. 5.

The main graph shows the percentage by weight of the constituents on the vertical scale and the concentration in grams per litre on the horizontal scale. The graph is plotted on millimetre squared paper, and the most compact scale has proved to be one-half millimetre to represent 1 per cent. on the vertical scale and one-half millimetre to represent one gram per litre on the horizontal scale.

Percentage by Weight.—This is plotted upwards from the base additively, in the following order, CO_3, HCO_3, Cl_2, Na and $Ca+Mg+SO_4$. Where SO_4 is a large quantity it is plotted separately, after the Na and followed by Ca+Mg.

Concentration in grams per litre.—The value used is the total of the grams per litre of the constituents used for calculating the percentage by weight and is not the value given for the total solids in solution. Silica, iron oxide and alumina and any other organic matter present, which possess no correlating value, are thus cut out from the estimation. The use of this value possesses another good feature in that the rectangle bounded by the constituent percentage by weight and the concentration gives an accurate representation of the total grams per litre of the constituent in the water analysed.

The alternate constituent rectangles are blacked in to give greater contrast. The same system must be adopted throughout—*i.e.*, if in one water there is HCO_3 and CO_3, and in another only HCO_3, the HCO_3 should be the constituent to be blacked in in both cases.

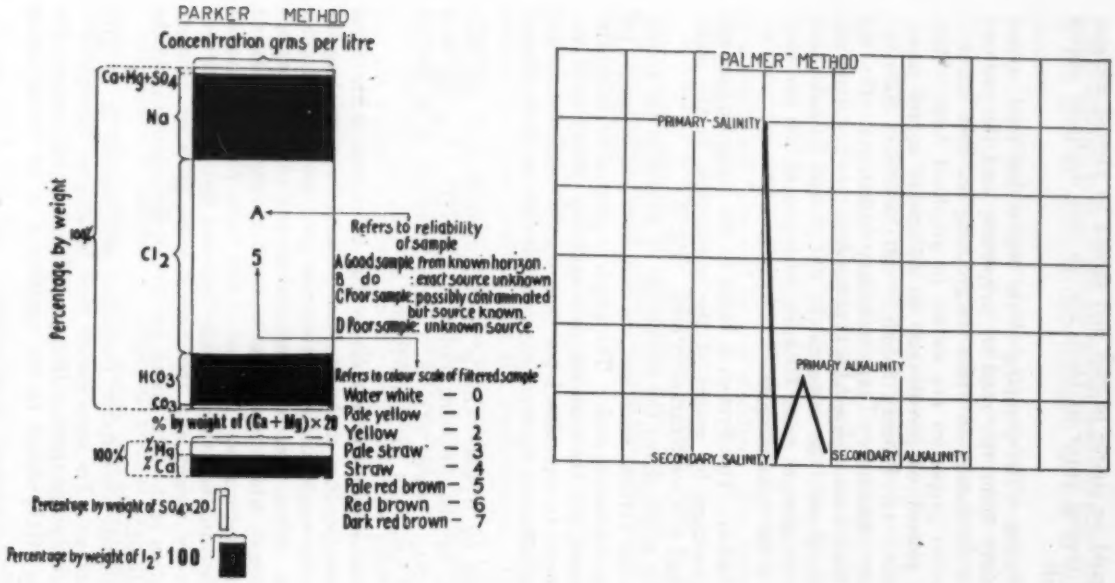


FIG. 5.

EXPLANATION OF GRAPHICAL METHOD OF ILLUSTRATING OIL WELL WATER ANALYSES.

A letter is entered in the Cl_2 rectangle to denote the reliability of the sample.

Reliability of Sample.

A—Good sample from known source.
B—Good sample; exact source unknown.
C—Poor sample; possibly contaminated but source known.
D—Poor sample; unknown source.

Below the letter is entered the colour number as noted from the scale :—

Colour	Scale.
Water White	0
Pale Yellow	1
Yellow	2
Pale Straw	3
Straw	4
Pale Red Brown	5
Red Brown	6
Dark Red Brown	7

As the calcium and magnesium are present in too small quantity to show any comparative difference on the main graph a smaller graph is drawn underneath the main graph to represent on a larger scale calcium and magnesium and the ratio calcium magnesium. The percentage by weight of calcium and magnesium in this case is taken to three places of decimals. The values obtained are added and the result multiplied by 20. The values are also worked out as a percentage of the total value—*e.g.* :—

PERCENTAGE BY WEIGHT.

Ca.	0·2		..	(0·184)
Mg.	0·4		..	(0·376)
		Ca. 0·184	..	33%
		Mg. 0·376	..	67%
		0·560		
		20		
		11·200		

5 mms. on the vertical scale represent 100 per cent. or 1 mm. equals 20 per cent. The percentages 33 and 67 are plotted from the base upwards and in the order Ca, Mg. One-half millimetre on the horizontal scale represents one unit of the final value for Ca plus Mg—*e.g.*, the above would be 1/2 (11·2) or 5·6 mms. For contrast the Ca rectangle is blacked-in. The graph gives a proportionate value for Ca plus Mg in the water and also the relationship between Ca and Mg.

As the sulphate is present in small quantity only, its value is increased in a similar manner by taking the percentage by weight value to three places and multiplying the result by 20. It is graphed by using 5 mms. vertically to represent 100 per cent. and one-half millimetre on the horizontal scale to represent one unit SO_4.

The iodine present is also of too low value to show up in the main graph. It is worked out in grams per litre. This figure is calculated to three places as a percentage of the total grams per litre of the constituents. The result is multiplied by 100 and graphed in similar manner to the SO_4,—*i.e.* 5 mms. equals 100 per cent. on the vertical scale and one-half millimetre equals one unit iodine on the horizontal scale. The iodine graph is blacked in.

The Parker System has the distinct advantage that it shows all the chemical characteristics of the water and its concentration at a glance. It gives CO_3 and HCO_3 both singly and additively. It gives a comparable value for calcium and magnesium and the relationship between the two. Lastly, it gives an indication of the change in any of the constituents of the well water instead of in a hypothetical combination of these constituents.

RESULTS OF INVESTIGATION.

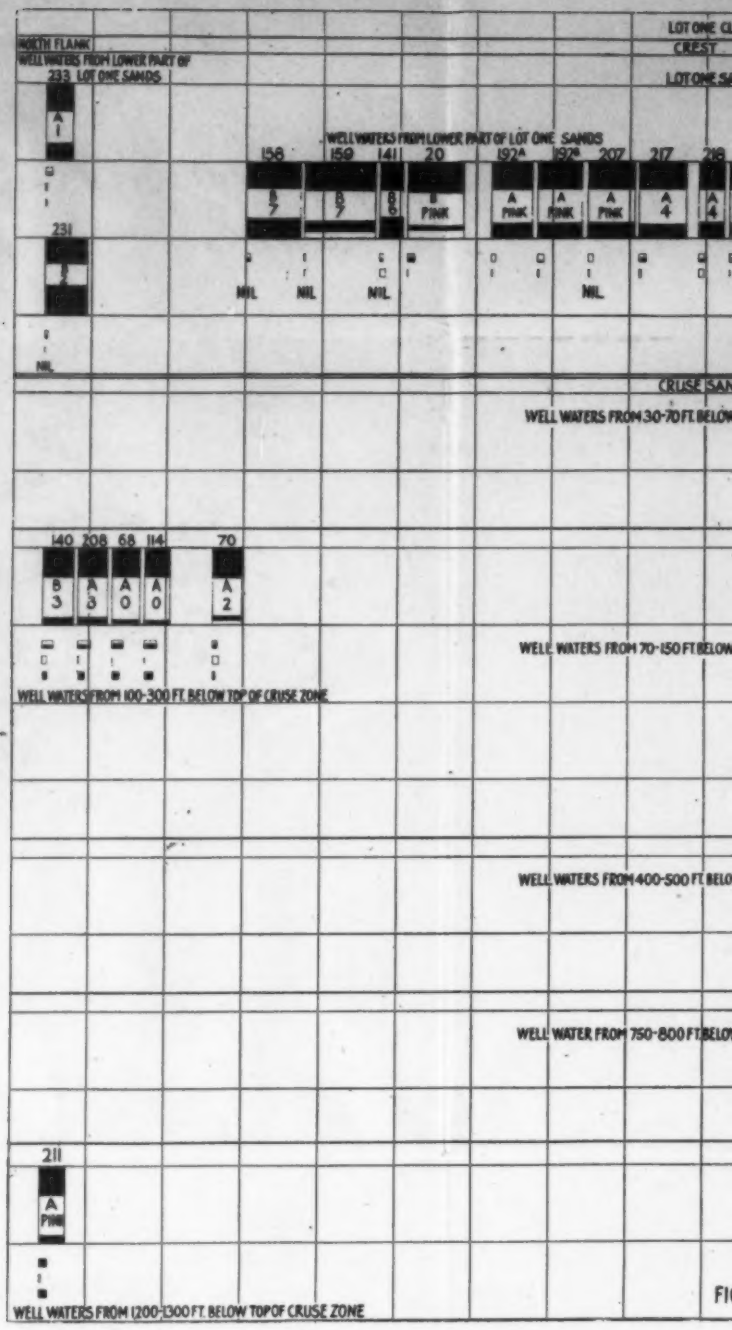
Brighton-Pitch Lake Structure.—There has been a considerable difference of opinion in the past regarding the age of the sands from which production has been taken in the structure underlying the Pitch Lake.

The wells were drilled over ten years ago, before coring and more up-to-date drilling methods were in operation, and knowledge of the Trinidad structures has progressed considerably since these wells were drilled.

Many Geologists have considered these sands to be representative of the Moruga Formation, but a careful examination of available data, both surface and sub-surface, indicates that the upper producing sands in this area are probably equivalent to the Lot One Sands of other structures. The sediments are similar to the Lot One sediments of other fields, and the general relationship of the oil sands and salt water-bearing sands is the same.

Only three analyses are available of well waters from wells drilled in this area. These waters have no iodine content, and in their other chemical features are very similar to the Parry Lands Lot One Waters.

Parry Lands Structure.—This consists of the plunging end or nose of a regular structure. In the crest of the structure the Lot


NORTH FLANK
WELL WATERS FROM LOWER PART OF
233 LOT ONE SANDS
WELL WATERS FROM LOWER PART OF LOT ONE SANDS
158 159 141 20 192A 192A 207 217 218
231
NIL NIL NIL NIL
LOT ONE CR
CREST
LOT ONE SA
CRUSE SAN
WELL WATERS FROM 30-70 FT. BELOW
140 208 68 114 70
WELL WATERS FROM 70-150 FT. BELOW
WELL WATERS FROM 100-300 FT. BELOW TOP OF CRUSE ZONE
WELL WATERS FROM 400-500 FT. BELO
WELL WATER FROM 750-800 FT. BELO
211
WELL WATERS FROM 1200-1300 FT. BELOW TOP OF CRUSE ZONE
FI

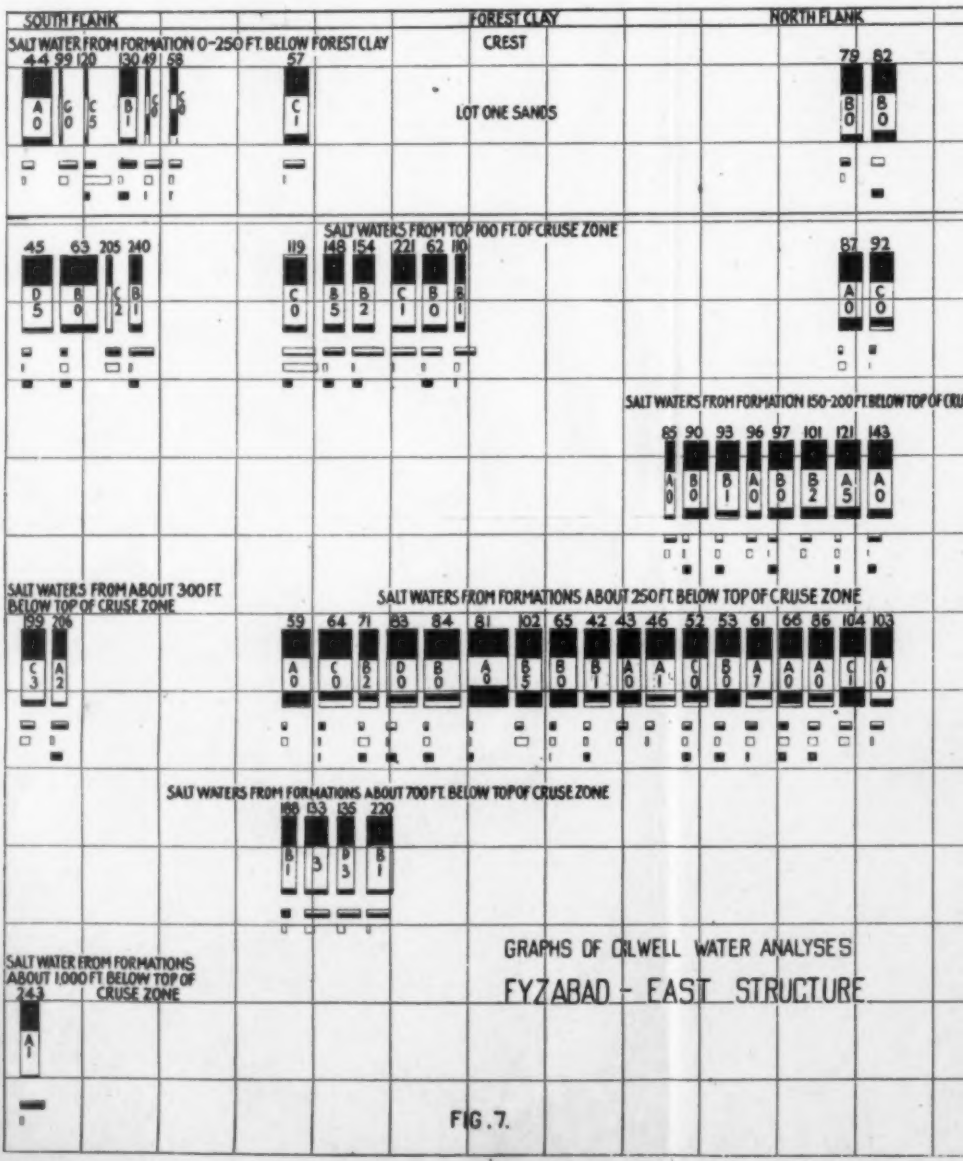

SOUTH FLANK
FOREST CLAY
NORTH FLANK
SALT WATER FROM FORMATION 0-250 FT. BELOW FOREST CLAY
CREST
44 99 120 130 49 58 57 79 82
LOT ONE SANDS
SALT WATERS FROM TOP 100 FT. OF CRUSE ZONE
45 63 205 240 119 148 154 221 62 110 87 92
SALT WATERS FROM FORMATION 150-200 FT. BELOW TOP OF CRU
85 90 93 96 97 101 121 143
SALT WATERS FROM ABOUT 300 FT. BELOW TOP OF CRUSE ZONE
199 206
SALT WATERS FROM FORMATIONS ABOUT 250 FT. BELOW TOP OF CRUSE ZONE
59 64 71 83 84 81 102 65 42 43 46 52 53 61 66 86 104 103
SALT WATERS FROM FORMATIONS ABOUT 700 FT. BELOW TOP OF CRUSE ZONE
188 133 135 220
SALT WATER FROM FORMATIONS ABOUT 1,000 FT. BELOW TOP OF CRUSE ZONE
243
GRAPHS OF OILWELL WATER ANALYSES
FYZABAD - EAST STRUCTURE.

FIG. 7.

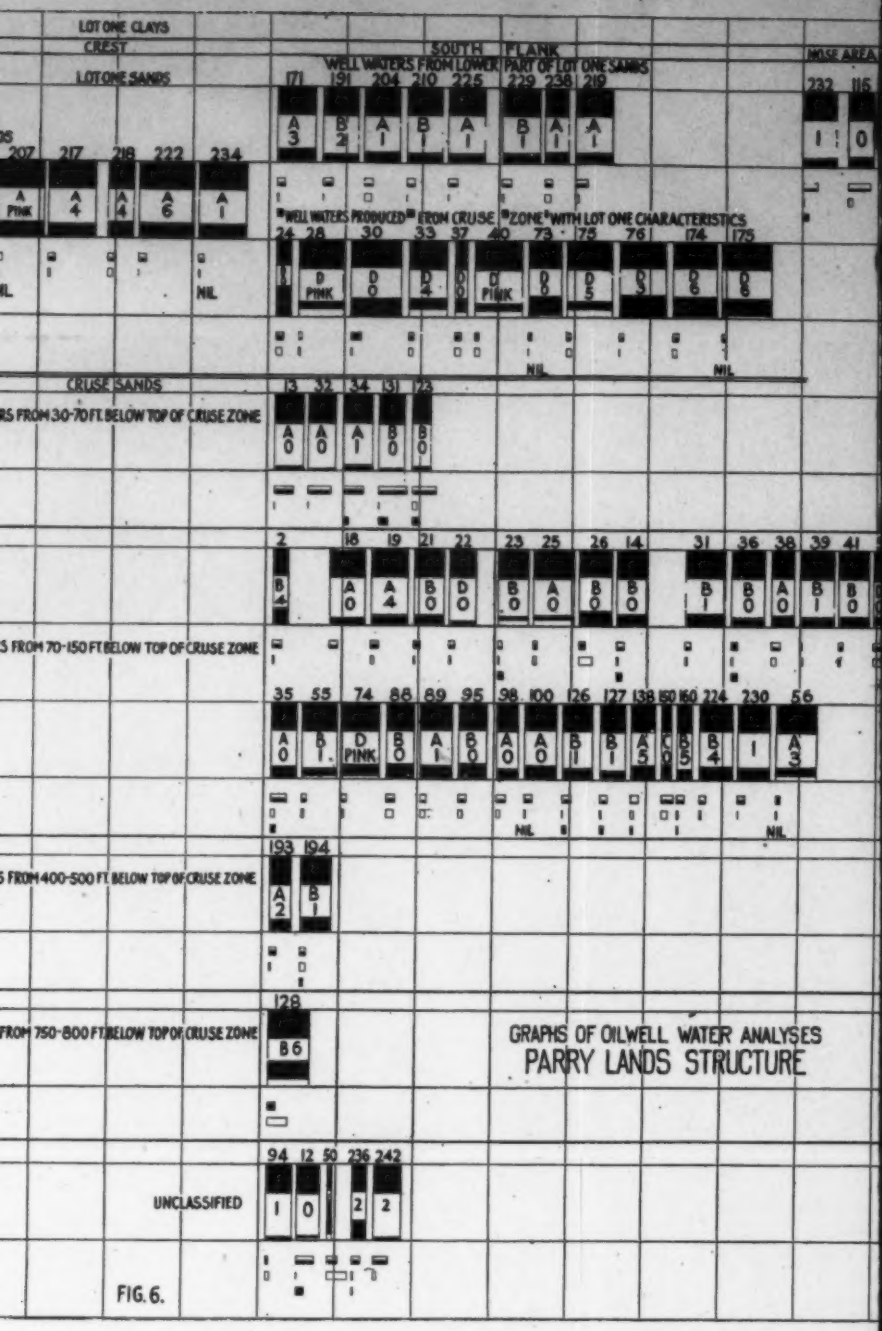
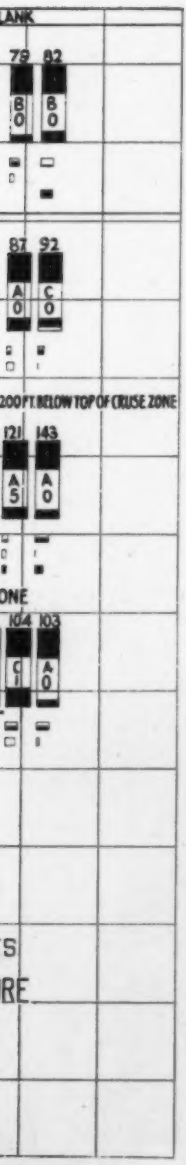

LOT ONE CLAYS
CREST
LOT ONE SANDS
SOUTH FLANK
WELL WATERS FROM LOWER PART OF LOT ONE SANDS
NOSE AREA
171 191 204 210 225 229 238 219 232 116
A 3 B 2 A 1 B 1 A 1 B 1 A 1 A 1 I 0
207 217 218 222 234
A PINK A 4 A 4 A 6 A 1
"WELL WATERS PRODUCED" FROM CRUSE "ZONE" WITH LOT ONE CHARACTERISTICS
24 28 30 33 37 40 73 75 76 174 175
D PINK D 0 D 4 D PINK D 6 D 5 D 5 D 6 D 6
NIL NIL NIL
CRUSE SANDS
13 32 34 131 123
A 0 A 0 A 1 B 0 B 0
RS FROM 30-70 FT. BELOW TOP OF CRUSE ZONE
2 18 19 21 22 23 25 26 14 31 36 38 39 41
B 4 A 0 A 4 B 0 D 0 B 0 A 0 B 0 B 0 B 1 B 0 A 0 B 1 B 0
S FROM 70-150 FT BELOW TOP OF CRUSE ZONE
35 55 74 88 89 95 98 100 126 127 138 150 160 224 230 56
A 0 B 1 D PINK B 0 A 1 B 0 A 0 A 0 B 1 B 1 A 5 A 0 B 5 B 4 I A 3
NIL NIL
193 194
S FROM 400-500 FT. BELOW TOP OF CRUSE ZONE
A 2 B 1
128
FROM 750-800 FT. BELOW TOP OF CRUSE ZONE
B 6
94 12 50 236 242
UNCLASSIFIED
1 0 2 2
GRAPHS OF OILWELL WATER ANALYSES
PARRY LANDS STRUCTURE

FIG. 6.


LANK
79 82
B 0 B 0
87 92
A 0 C 0
200 FT. BELOW TOP OF CRUSE ZONE
121 143
A 5 A 0
ONE
104 103
C 1 A 0
S
RE

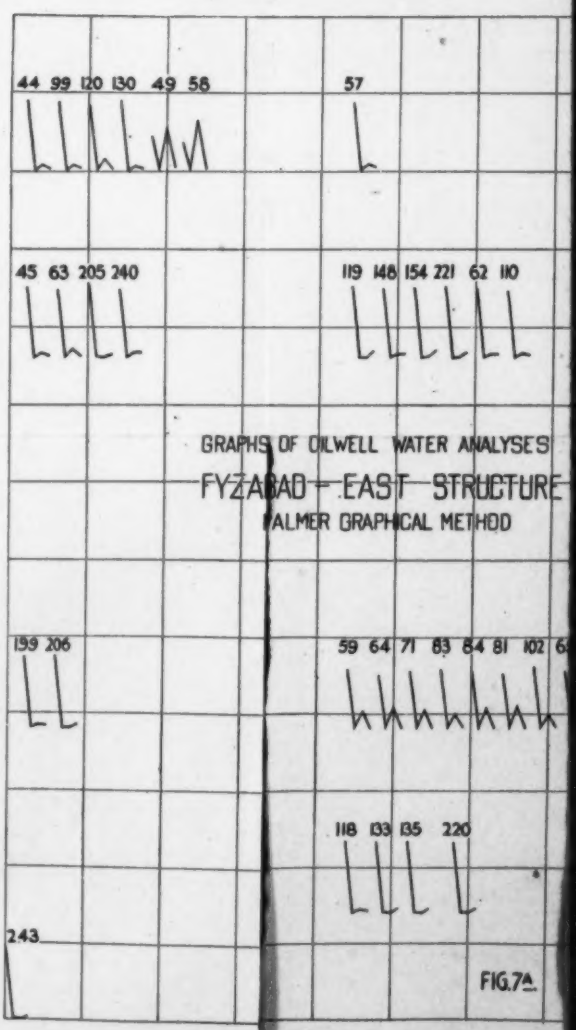
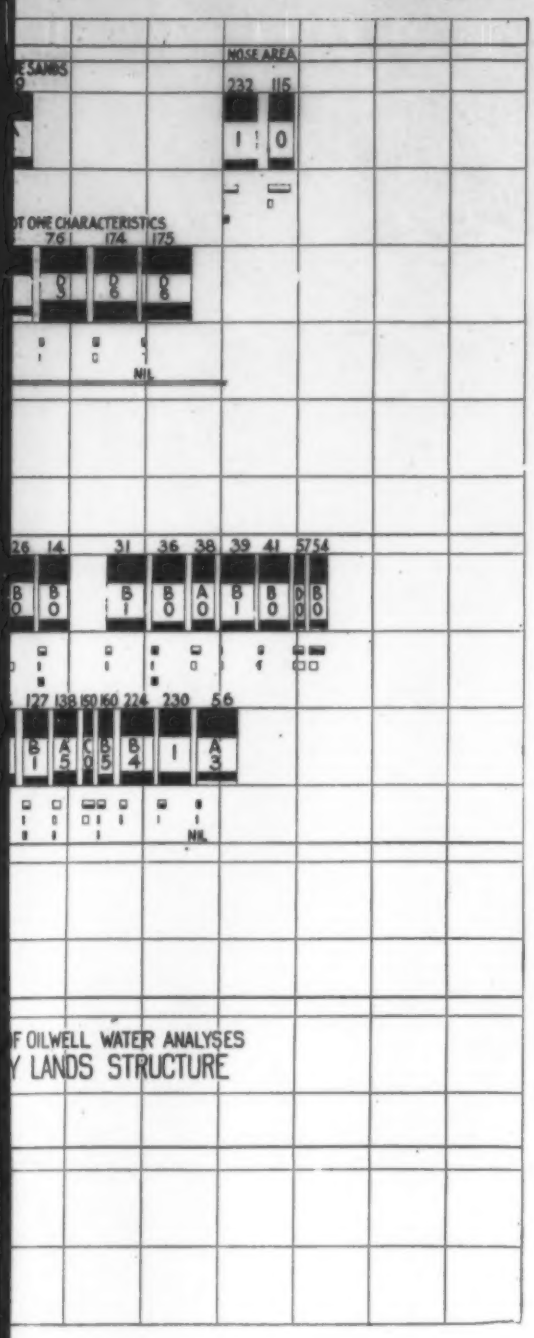
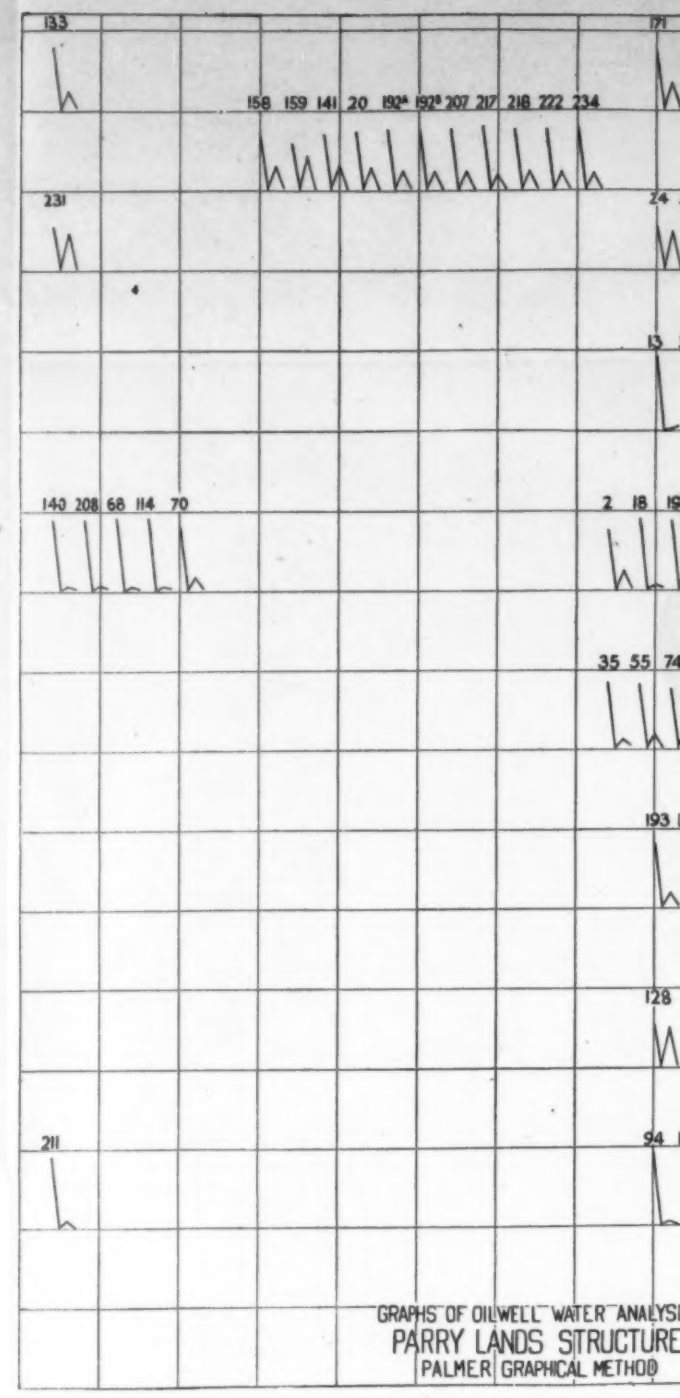
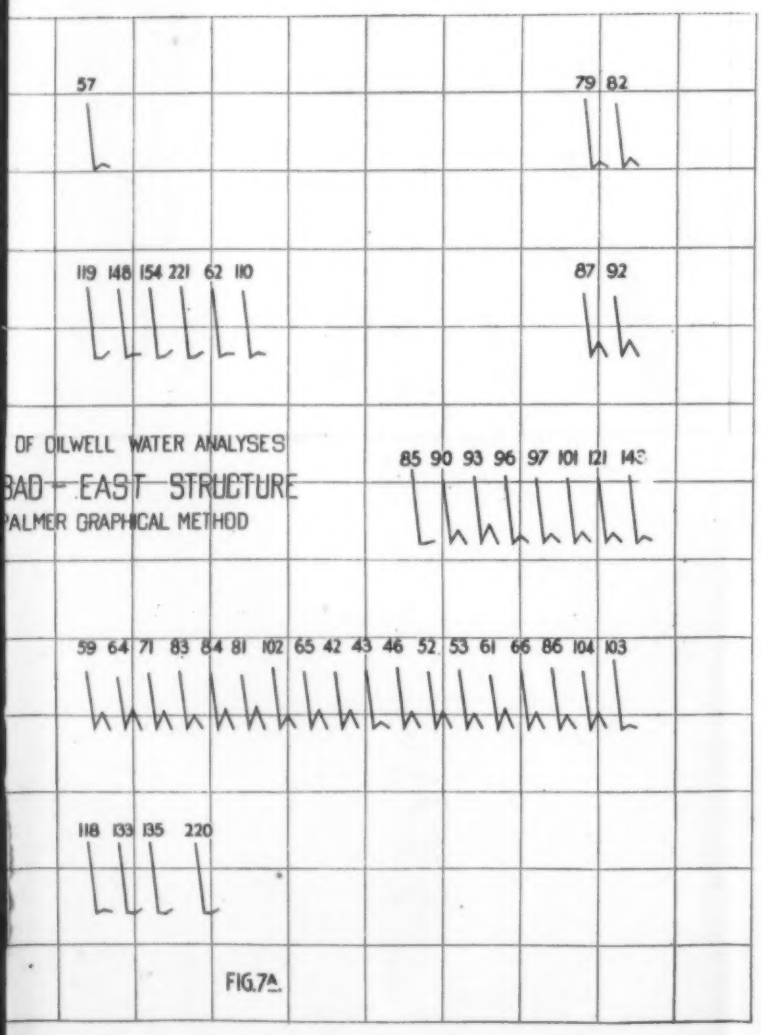
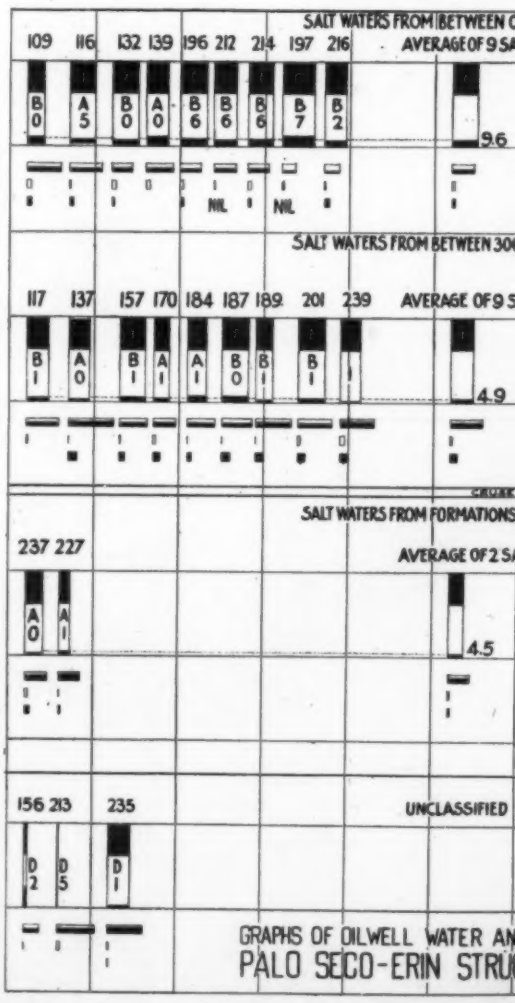

44 99 120 130 49 58
57
45 63 205 240
119 148 154 221 62 110
GRAPHS OF OILWELL WATER ANALYSES
FYZABAD - EAST STRUCTURE
PALMER GRAPHICAL METHOD
199 206
59 64 71 83 84 81 102
118 133 135 220
243

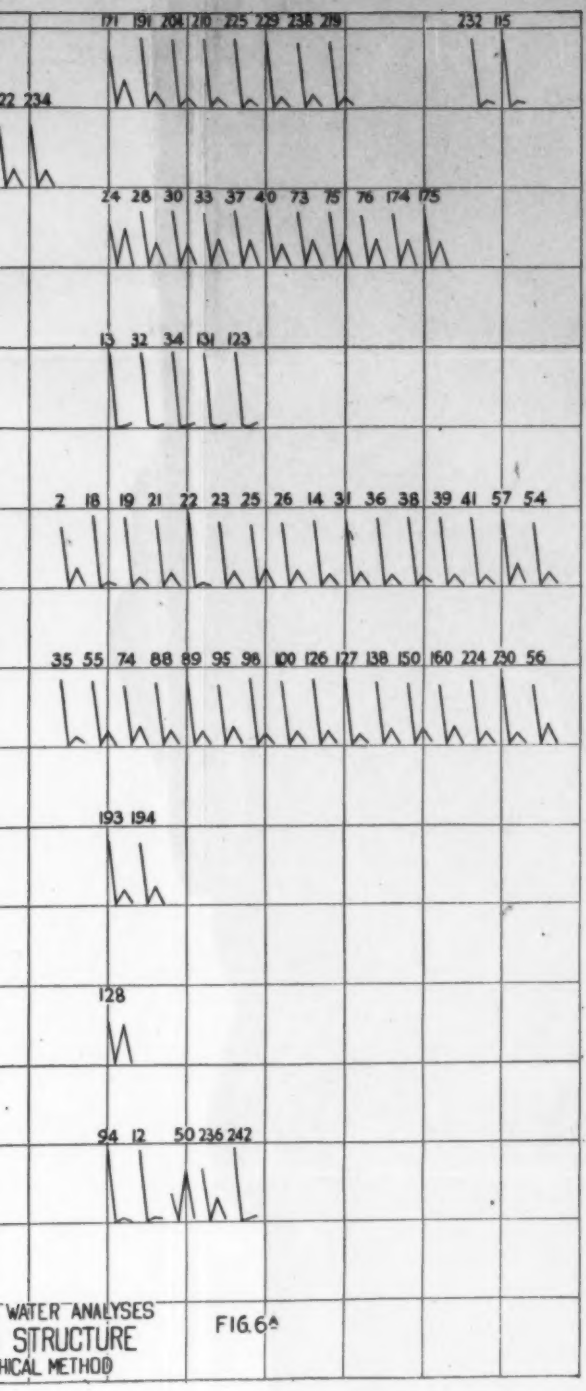
FIG. 7A.


NOSE AREA
232 115
I 0
T ONE CHARACTERISTICS
76 174 175
NIL
26 14 31 36 38 39 41 57 54
127 138 150 160 224 230 56
NIL
F OILWELL WATER ANALYSES
Y LANDS STRUCTURE


133
158 159 141 20 192A 192B 207 217 218 222 234
231
140 208 68 114 70
2 18
35 55
193
128
211
94
GRAPHS OF OILWELL WATER ANALYSI
PARRY LANDS STRUCTURE
PALMER GRAPHICAL METHOD

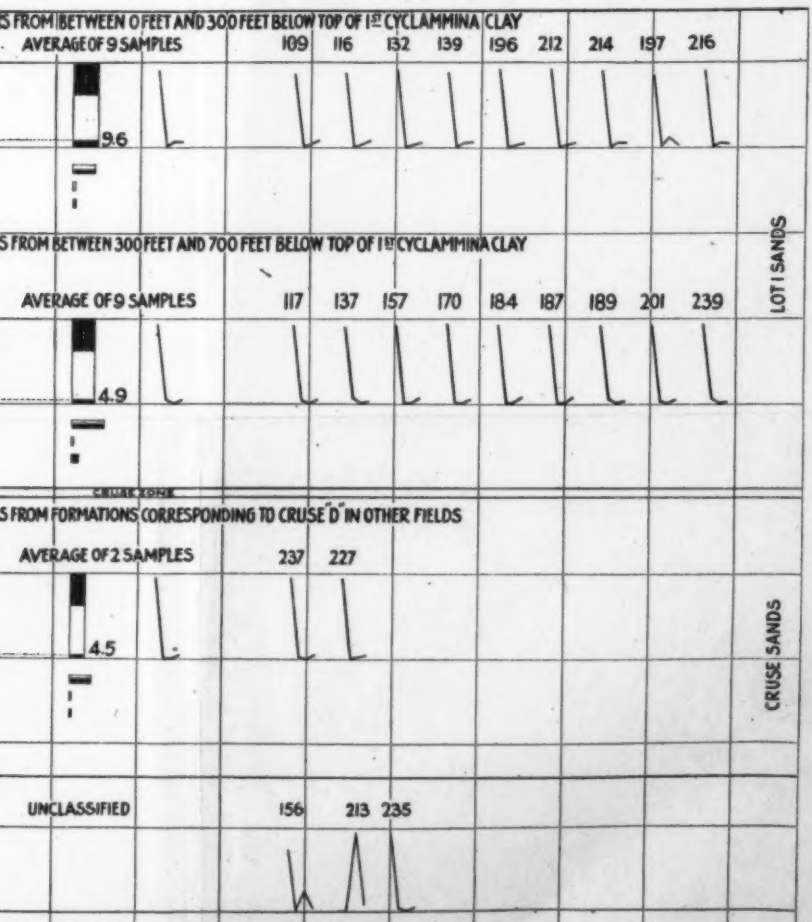

57
79 82
119 148 154 221 62 110
87 92
OF OILWELL WATER ANALYSES
BAD - EAST STRUCTURE
PALMER GRAPHICAL METHOD
85 90 93 96 97 101 121 143
59 64 71 83 84 81 102 65 42 43 46 52 53 61 66 86 104 103
118 133 135 220
FIG.7A.


SALT WATERS FROM BETWEEN
109 116 132 139 196 212 214 197 216
AVERAGE OF 9 SA
9.6
NIL
NIL
SALT WATERS FROM BETWEEN 300
117 137 157 170 184 187 189 201 239
AVERAGE OF 9 S
4.9
SALT WATERS FROM FORMATIONS
237 227
AVERAGE OF 2 SA
4.5
156 213 235
UNCLASSIFIED
GRAPHS OF OILWELL WATER AN
PALO SECO-ERIN STRU



WATER ANALYSES
STRUCTURE
HICAL METHOD

FIG. 6A


S FROM BETWEEN 0 FEET AND 300 FEET BELOW TOP OF 1st CYCLAMMINA CLAY
AVERAGE OF 9 SAMPLES
109 116 132 139 196 212 214 197 216
9.6
S FROM BETWEEN 300 FEET AND 700 FEET BELOW TOP OF 1st CYCLAMMINA CLAY
AVERAGE OF 9 SAMPLES
117 137 157 170 184 187 189 201 239
4.9
LOT I SANDS
CRUSE ZONE
S FROM FORMATIONS CORRESPONDING TO CRUSE "D" IN OTHER FIELDS
AVERAGE OF 2 SAMPLES
237 227
4.5
CRUSE SANDS
UNCLASSIFIED
156 213 235

VELL WATER ANALYSES
-ERIN STRUCTURE

FIG. 8. PALMER GRAPHICAL METHOD

One Clays outcrop, and the sequence of strata proved by drilling is as follows:—

Morne L'Enfer Sands.
Lot One Clays.
Lot One Sands.
Intermediate Clays.
Cruse Sands.
Cruse Clays.

Salt water-bearing formations are fairly consistent in the lower part of the Lot One Sands, but the water samples analysed can be grouped into three main chemical provinces from different parts of the structure. (Figs. 6 and 6A.)

A salt water-bearing zone has been proved on the south flank the Cruse Zone. Insufficient data have been obtained of the salt water saturation has a limited distribution.

Towards the syncline on the south flank a salt water accumulation with a temperature of 105° F. has been proved in formations 30–70 ft. below the top of the Cruse Zone, which forms a separate chemical province, and in Lot Four a salt water accumulation has been proved of limited extent about 400–500 ft. below the top of the Cruse Zone. Insufficient data have been obtained of the salt water accumulation about 150 ft. below the top of the Cruse Zone.

Waters derived from this structure readily arrange themselves into two groups: (1) Waters from the Lot One sands; (2) Waters from the Cruse Zone. There are marked chemical differences in the waters derived from these zones, and the chemical correlation of the waters is simpler than on any other structure except Palo Seco.

If one starts with these two groups only, the characteristics of the waters are markedly similar in chemical variations to those on the Palo Seco field. The most concentrated waters are in the Lot One sands, and the concentration varies inversely with depth. The Lot One waters are on the whole dark coloured, and the majority of the Cruse Waters are either light yellow or water white. The Carbonate plus Bicarbonate percentage varies inversely with the depth, and the Nil iodines are all present in the top waters. The Nil iodine theory will be taken up under "Conclusions."

The waters in the Lot One Zone have been separated into three groups. Two groups are similar in that they have high concentration, high Carbonate plus Bicarbonate content, and Nil iodine. The third group has lower concentration and lower Carbonate plus Bicarbonate content than the other two, and the samples analysed for iodine have shown an average iodine content. This "Lower part of the Lot One Sands group" of waters is situated on the other side of a known fault from the other group marked

"Lower part of the Lot One Sands." The lower concentration, the lower Carbonate plus Bicarbonate content, and the presence of iodine would suggest that this group of waters has been at one period or another in contact with waters from the *Cruse Zone*. If this theory is accepted as correct then there has been movement of water from the Cruse Zone to the Lot One Zone, and this hypothesis is to a certain extent confirmed by the faulted nature of this area.

The Cruse waters have been sub-divided into two main groups :—

(1) 30 to 70 ft. below top of Cruse Zone.

(2) 70 to 150 ft. below top of Cruse Zone.

The first group is readily distinguishable from any other in that it has normal concentration, low Carbonate plus Bicarbonate content, high Calcium plus Magnesium content and an average iodine content. The Calcium/Magnesium ratio is about 50/50.

The second group of waters is intermediate between the 30/70 Cruse group and the true Lot 1 waters, i.e. those containing Nil iodine. Concentration, Carbonate plus Bicarbonate content, Calcium plus Magnesium content are all intermediate but nearer the Lot 1 type than the 30/70 type.

An isolated patch of water on another part of the structure is shown in the 70/150 zone. This group correlates chemically, and is also intermediate between the Lot 1 and the 30/70 Cruse, but in this case the chemical characteristics are nearer the 30/70 group.

The 400/500 Cruse group is an isolated patch of water with similar chemical characteristics to the 70/150 group.

Fyzabad Structure.—This structure runs from San Francique in a westerly direction into the Forest Reserve where it joins with the Point Fortin Structure. It comprises several domal areas and has been divided into Fyzabad East and Fyzabad West.

Fyzabad East.—The stratigraphical details and conditions of sedimentation in this area are well defined, consisting of the Morne L'Enfer Sands, the Forest Clay or Upper Cyclammina Clay, the Lot One Sands, or A, B, C and D Sands, the Cruse Zone or E,F, G and H Sands, and the Cruse Clays. The structural details have been precisely defined by the identification of the base of the uppermost Cyclammina Clay, known as the Forest Clay, and all salt water accumulations have been related to this stratigraphical horizon.

On the south flank, salt water-bearing sands are usually found immediately underlying the Forest Clay, this being in part a general watered zone similar to the Palo Seco Area. In certain

areas on the Fyzabad Structure, commercial accumulation is obtained from this horizon showing that, although this zone is partly watered, the watered areas are of limited extent. These salt waters show consistent chemical characteristics. Figs. 7 and 7A. A small amount of evidence of occasional salt water lenses lower in the Lot One Sands has been obtained, but these lenses are rare and in general the lower part of the Lot One Sands in this area is not water-bearing.

The area between Fyzabad East and Fyzabad West comprises a structural saddle with considerable tectonic adjustment, and in this area salt water-bearing formations have been proved about 250 ft. below the top of the Cruse Zone which have consistent chemical characteristics over a considerable area.

Further east, on the north flank, an area of salt water accumulation has been proved in the Cruse Zone between 150 ft. and 200 ft. below the top of this zone. These waters form a separate chemical province.

Proceeding further eastwards towards San Francique an area has lately been proved in which salt water-bearing strata has been found at several wells at about 100 ft. below the top of the Cruse zone, in horizons which to the west are usually commercially productive.

Occasional salt water-bearing strata of a lenticular nature have proved at deeper horizons, within the Cruse Zone, the deepest being about 1,000 ft. below the top of this zone. These main groups of salt water-bearing formations, irregularly distributed within the structure, from which reliable samples have been chemically examined, can be differentiated by the chemical characteristics of the salt waters.

The waters from this structure possess marked chemical resemblance to the waters from the Parry Lands Structure. In one zone only do they differ, the Lot One Sands, and, because of this difference, the Parry Lands water problem is simpler. The pronounced chemical features of the Parry Lands Lot 1 waters readily identify them from the Cruse Waters, but, on the Fyzabad-East structure, there is no marked difference between the chemical features of the Lot 1 waters and those from the Cruse Sands. It is practically impossible, as far as present analytical results show, to isolate the Lot 1 waters on this latter structure by means of their chemical characteristics. The correlation of the samples shown in this Report has been carried out from geological evidence and checked by the chemical characteristics of the waters.

The Cruse Zone Waters are much simpler and bear a marked resemblance to the Parry Lands Cruse Waters. The top 100 ft. Fyzabad-East waters are very similar in chemical characteristics

to the 30/70 ft. Parry Lands. The 200/300 ft. Fyzabad-East are of similar chemical construction to the 70/130 ft. Parry Lands, even to the isolated water lenses shown under these groups on each structure. The 150/200 ft. Fyzabad-East Waters are intermediate between top 100 ft. and 200/300 ft. in chemical characteristics. This water is either not present on the Parry Lands Structure or has been included under 70/150 ft. Parry Lands.

The 700 ft. Fyzabad-East Waters are typical of what one would expect under the 200/300 ft. Fyzabad-East and 70/150 ft. Parry Lands.

There is more evidence on this than on any other structure of discontinuity of the water zones. Waters derived from similar stratigraphical horizons show differences in chemical characteristics.

The general chemical characteristics of the Cruse Waters on this structure are :—

Top 100 ft.—Normal concentration, low Carbonate plus Bicarbonate content and high Calcium plus Magnesium content.

200/300 ft.—High concentration, when considering this structure alone, high Carbonate plus Bicarbonate content and low Calcium plus Magnesium content.

150/200 ft.—Intermediate between top 100 ft. and 200/300 ft. but nearer the 200/300 ft.

600 ft.—Low concentration, low Carbonate plus Bicarbonate content and intermediate Calcium plus Magnesium content.

On this structure the Lot One Waters are chemically similar to the Cruse Waters and also contain iodine. This structure does not possess the thick zone of impervious clays dividing the Lot One sands from the Cruse sands which is found at Parry Lands. This may be the reason for this similarity. The chemical results indicate that the waters in the Lot One sands and the waters in the Cruse Zone have at some time had contact.

Fyzabad-West Structure.—This area includes the Bernstein Dome. The conditions of salt water accumulations in the upper sands of this structure are somewhat different from those on the Fyzabad-East structure, and different well programmes are required.

The main zone from which salt waters have been obtained is the lower part of the Lot One Sands. This is similar to the Lot One salt water accumulations of the Parry Lands Structure to the north.

The waters from this structure which have been analysed are markedly similar in chemical characteristics, due probably to the consistently sandy nature of these sediments and the more general salt water saturation of the zone. They have high Carbonate plus

Bicarbonate content, low Calcium plus Magnesium content, the calcium is present in lower quantity than the magnesium and the sulphate content is low. In all chemical features, except concentration, these waters are very similar to the Parry Lands Lot One Waters.

Insufficient data have been obtained from the Cruse Zone to give any statement of salt waters within this zone in this area.

It is rather interesting to note that, as one proceeds westwards along this main structural uplift from the Bernstein Dome, the salt water accumulation appears to become less, and very little data regarding the characterisation of salt waters from the dome structure immediately west of the Bernstein Dome are available. Great thicknesses of formations are open to perforations in this structure and very few salt waters have been observed. Salt water has been proved within the Cruse Zone on the south flank, and in a small area on the north flank, where an accumulation has been found in the Lot One Sands, but no chemical data are available on these waters.

Palo Seco Structure.—The structure at present being operated between Palo Seco and Erin is situated on the north flank of the main southern uplift which runs in a north-east-south-west direction paralleling the main orogenic movement. The conditions of sedimentation in this area are in general similar to those of the other fields in the south-west.

Immediately below the Upper Cyclammina Clay in the Palo Seco Area it is usual to find water-bearing sands, although, in certain instances, due to lateral differences in sedimentation, commercial oil has been obtained. This water-bearing zone has been taken as about 200 ft. thick, from which several reliable samples of the waters have been chemically examined. These samples show that the accumulation of salt water in this zone is chemically similar within the area drilled. (Fig. 8.)

Commercial production is obtained below this zone from the lower 500ft. of the Lot One Sand Series. Within this 500 ft. occasional accumulations of salt water have been proved which do not, from the evidence accumulated, fall into such a limited stratigraphical zone as the group of salt waters mentioned above. They do, however, form a chemical province, and can be differentiated from the upper zone salt waters by chemical characteristics if reliable samples are analysed.

Flowing salt waters have been proved in the Cruse Zone from horizons about 400–500 ft. below the top of this zone. Little drilling has been undertaken in this zone as the upper sands are at present being produced, and only three samples of salt water have

been obtained. These are reliable samples and indicate that the salt water accumulations in the Cruse Zone differ chemically from those in the Lot One Sands.

The first point to be noted in the chemical consideration of the Palo Seco Waters is the concentration. This apparently varies inversely with depth, the most concentrated water being found just below the Forest Clay and the least concentrated water in the Cruse Zone. This is contrary to the fundamental principles of salt water accumulations, and will be dealt with collectively under conclusions.

The CO_2 is present almost entirely as bicarbonate, and the total of carbonate and bicarbonate also varies inversely with depth.

The colour of the waters is interesting, as the top waters are on the whole dark coloured, and the lower waters very light coloured or water white.

The maximum Calcium plus Magnesium content is apparently present in the middle group of waters. The ratio Calcium/Magnesium, however, is more important. Calcium is present in equal proportions to the magnesium in the waters immediately below the Forest Clay, but bears a relationship about 60/40 to the magnesium in the waters present in the lower part of the Lot One Sands and a relationship about 80/20 in the Cruse Zone. The proportion of calcium increases directly with the depth.

The middle group of waters contains the largest amount of Iodine. It will be noted that Nil iodine is returned for the top waters only.

Sufficient data have been obtained to show that the salt water accumulations in this area are limited in extent, due to lateral variation in the porosity of the sediments.

Barrackpore Structure.—This structure forms the northern limb of the main southern syncline. The exact relationship of the sediments from which production is obtained to the producing zones of the main fields to the west has not been determined, and opinions differ as to whether these are the equivalent of the Lower Morugas or the Upper Naparimas.

There is not sufficient evidence available at the present time to define this relationship, and, for the purpose of the study of the well waters, the horizons from which these waters are produced have been considered as equivalent to the Lot One Sands of other fields. If this is so they correspond to the Lot One Waters found on the Palo Seco Structure and not to the Parry Lands Lot One's.

Owing to the chemical similarity of the waters analysed, they have all been grouped together, althought it is known that they are derived from different horizons within about 500 ft. of strata.

FIG. 9.

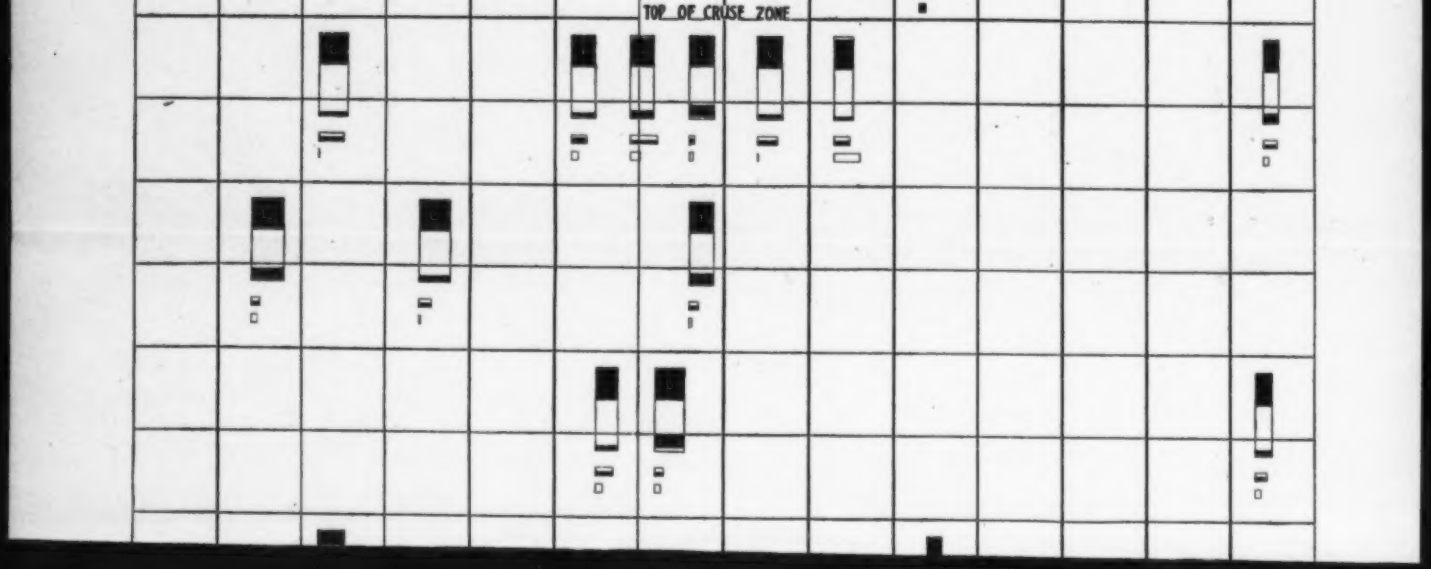
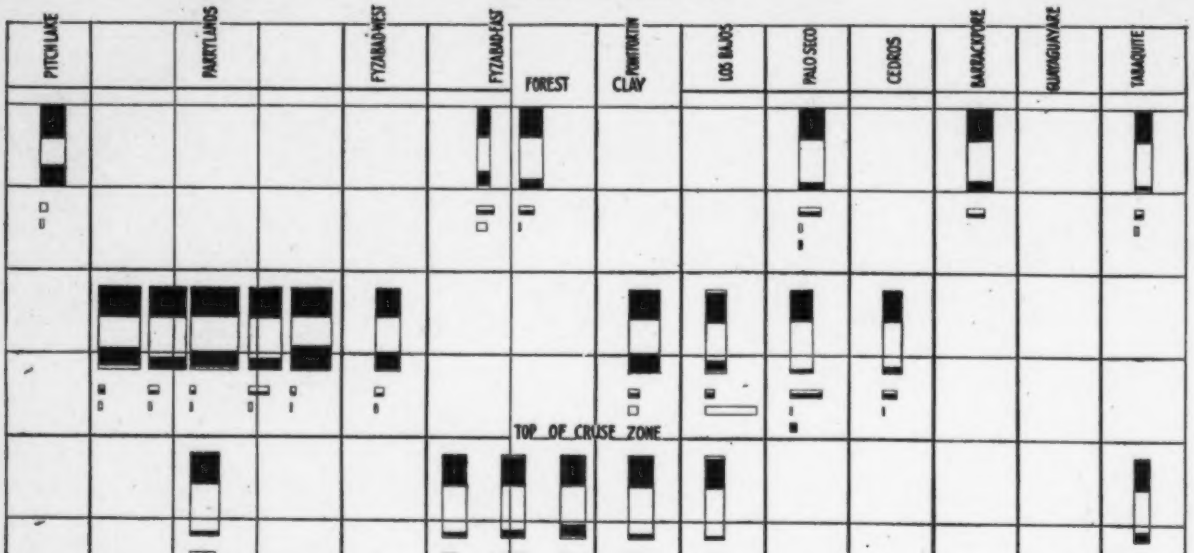

TOP OF CRUISE ZONE

CHART SHOWING CHEMICAL CHARACTERISTICS OF SALT WATERS ENCOUNTERED IN THE TRINIDAD STRUCTURES

ARRANGED STRATIGRAPHICALLY



Tabaquite Structure.—The structure at Tabaquite from which commercial production is obtained has always been a controversial question with Trinidad geologists. The lithological character of the upper producing sands differs considerably from that of the fields in the south-west. The foraminiferal evidence indicates that the upper sands at Tabaquite are, more or less, of similar age to the producing sands of the south-west. It is impossible to correlate this field stratigraphically with the other producing fields, and, therefore, no correlation of the chemical results of the well waters with those of other fields has been attempted. The results have been zoned in accordance with the geological data available.

Chemical consideration of the geological groupings would show that there is variation in the chemical constituents of the groups, but that it is small. This variation follows approximately that noted on the Palo Seco Structure. The Carbonate plus Bicarbonate varies inversely with depth. The total of calcium and magnesium increases from the waxy oil zone to the non-waxy oil zone, and there is an increase in the percentage of calcium in the ratio calcium/magnesium. The sulphate content varies directly with the depth. The high sulphate content in the waters on this structure is probably due to their having had intimate contact with pyrites waters. Evidence for this is obtained from the pyritical nature of the foraminifera in the faulted area to the south of the field.

SEA WATER AND WELL FRESH WATER.

Analyses were carried out to obtain data on (1) the sea water surrounding the Island of Trinidad, and on (2) the fresh water obtained from wells drilled to shallow depths.

The sea water in the partly enclosed Gulf of Paria, except for a slight difference in magnesium content, is exactly similar to sea water obtained from the open sea conditions on the Palo Seco side. Both waters are essentially chloride waters; they contain very small CO_2 content, and the majority of this is present in the form of bicarbonate; the sulphate content is high and the Calcium plus Magnesium content is higher than is present in Trinidad well salt waters. (Fig. 10.)

Two points of importance are:—

1. That the total solids content of the sea water is very similar to the total solids content of the majority of the Trinidad well salt waters.

2. That no iodine is present in the sea water on either side of the Island.

A further sample of Gulf of Paria sea water was tested when this water was contaminated by flood water from the Orinoco and flood water from the Trinidad shore. The points to be noted are :—

1. The evidence of dilution—lower value for total solids.
2. Higher carbonate content. This sample was calculated out as carbonate, but it is probable that the majority of the CO_2 was present as bicarbonate.
3. No iodine present.

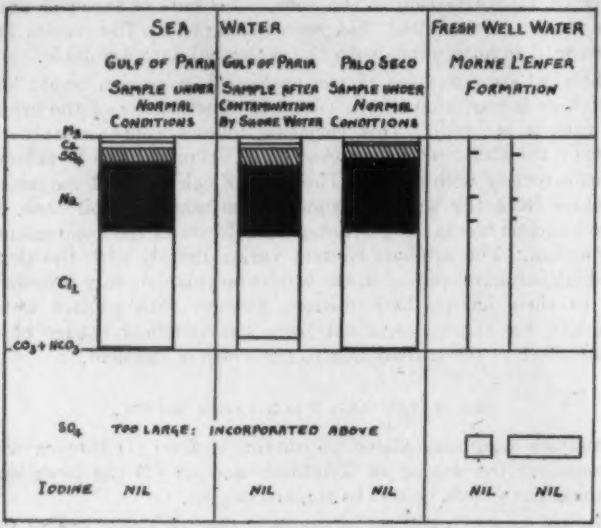


FIG. 10.

CHART SHOWING CHEMICAL CHARACTERISTICS OF SEA WATER AND WELL FRESH WATER.

Samples of waters derived from wells drilled to shallow depths for a fresh water supply were tested. Results proved that these waters are essentially bicarbonate, that they contain an exceedingly high percentage of bicarbonate, and that the sulphate percentage is normal compared with well salt water sulphate percentage. No iodine was present in either of the samples tested.

CONCLUSIONS.

It would appear that the waters in which the Miocene Sediments of the southern half of Trinidad were deposited were essentially Chloride waters, somewhat similar to the water of the Gulf of Paria to-day.

The Gulf of Paria is an example of the primary processes of sedimentation which have taken place in former geological times. The Gulf is gradually sanding up with the deposition of fine sediments. At certain periods of the year the water is freshened by flood water from the Orinoco and from the Trinidad shores. This water contains clay in suspension which is gradually deposited. Although the sands after deposition are probably saturated with typical connate water, it is probable that this becomes slightly contaminated by the fresher flood water before the deposition of the clay seal. Consideration of the analysis of the Gulf of Paria sea water sample taken during the flood period would suggest that the water laid down with the sediments contained a small percentage of bicarbonate, say 1 per cent. This percentage would probably be higher if the bicarbonate content of the flood water had not been taken up to a great extent by the abundant organisms of the tropical seas. If the well salt waters were originally of this type then it is necessary to account for their present high bicarbonate content.

The Trinidad well salt waters which have been analysed are essentially bicarbonate waters, and the general average of the bicarbonate content is high. Very few of the waters approximate to a typical chloride water. This would tend to indicate that the waters were meteoric or that they were of mixed meteoric and connate type. Consideration of the data accumulated would, however, appear to prove that the high bicarbonate content is due to a secondary process, and that it was not present in the original waters.

It is reasonable to assume that the connate chloride water was gradually forced by pressure due to earth movement and the superincumbent strata into the porous sands suitable for its accumulation. These sands are irregularly distributed within the clayey or silty matrix. During the gradual migration of the connate water into its present underground reservoirs it acquired bicarbonate features from the organic remains laid down with the sediments. In view of the fact that the calcareous and organic content of the sediments through which the original connate water migrated was irregular, it is only to be expected that the bicarbonate feature of the saline waters would differ slightly from final accumulation to final accumulation, a condition which has been confirmed by the chemical research undertaken.

In Trinidad the salt waters so far encountered must all be considered as Intermediate Waters, as they are overlain and underlain by strata containing oil-saturated sands.

The distribution of the salt water accumulations of the oil-producing series of Trinidad is very irregular both laterally and stratigraphically. A horizon which has proved to be salt water-bearing

on one part of a structure may be found to be free from salt water in another part of the same structure. This is even more pronounced when considering the salt water relationship from structure to structure.

No satisfactory theories have been evolved to account for the position of the salt water accumulations on the structures, and, in drilling on the crestal part, it has been found that salt water has been trapped due to lateral variation of the sediments, and that the synclinal areas have not, as one would expect, a general salt water accumulation. The synclinal areas in so far as they have been exploited have shown irregular distribution of salt water accumulations similar to that found on the higher part of the structures. It is interesting to note that more salt water accumulations are to be found in areas which have suffered most stress.

The irregular Carbonate plus Bicarbonate features of the different salt water accumulations which have been proved in every field confirm the geological conclusions previously drawn from the interpretation of the geological data.

The chief difficulty experienced in the chemical correlation of the well salt waters is the lack of any marked differences in their chemical characteristics. Most of the correlation work has been carried out on small differences in the Carbonate plus Bicarbonate content and in the Calcium plus Magnesium content. The main methods of well water correlation on other fields are usually dependent on :—

1. Increase in concentration with depth.
2. Decrease in sulphate content with depth.
3. Decrease in Carbonate plus Bicarbonate content with depth.

These conditions have not been found in Trinidad, and therefore these methods cannot be applied. It is interesting to note that, when any of these features vary directly or inversely with depth in any one of the Trinidad structures they do so in a reverse manner to that generally expected. The sulphate content on the Tabaquite structure increases with depth, and the concentration on practically all the structures varies inversely with depth. The Carbonate plus Bicarbonate feature when the Cruse Zone is considered as a whole does show a decrease from that found in the Lot One Sands.

In addition, the majority of the waters in the oil-producing series are under a low hydrostatic head unless flowed to the surface by gas. This factor permits of the mudding off of the water during drilling with the general use of the mud flush rotary system, so that it is difficult, unless a gas flowed water is encountered, to obtain uncontaminated samples for chemical examination.

Owing to the irregular chemical characteristics of the waters the chemical results have not been of great use to the geologist in the interpretation of the sub-surface condition. There is no doubt that, as the chemical study proceeds, the results will be of use in correlating from well to well in structures where geological markers are not available. In one field the correlation has been based mainly on the position of the water sands and oil sands in the wells, and, had samples of the salt waters been analysed, there is no doubt that these data would have materially assisted the geologist.

On certain structures the limits of a salt water accumulation have been proved by drilling, and, within this area, the salt water from the one zone proved to have regular chemical characteristics. These are important data, as they indicate the extent of a continuous porous body, and future investigation along these lines will no doubt assist in the interpretation of the conditions of oil and salt water accumulation, especially with regard to drainage problems.

The sulphate content of the well salt waters is on the average extremely low; whereas the sea water samples analysed show high sulphate content. This point has been noted and investigated by observers on other fields. It is generally admitted that the sulphate breaks down through chemical interaction with hydrocarbons and other organic matter with the resultant addition of carbonate to the water.

The well salt waters on the average closely approximate in concentration to the concentration of the sea water surrounding the Island. Only on the Parry Lands Structure is there evidence of salt waters of marked higher concentration, and these waters are encountered in the Lot One Zone. If we assume that the sea water in the Gulf of Paria is typical of the waters originally laid down with the Miocene Sediments then these fossil waters have undergone no marked concentration except in one area. In those areas which show marked grading of the concentration with depth the concentration is found to vary inversely with the depth. This is exactly the reverse of what one would expect and can only be explained by the assumption that the zones of high concentration have at some time been the zones of large gas accumulations and intensive gas action.

It has been noted under the remarks on individual structures that there is a marked similarity in chemical characteristics between the waters on the two structures Fyzabad-East and Parry Lands. Except for the Lot One waters, the waters on the one structure can be correlated across chemically with the waters on the other structure. The waters on these structures have been more fully investigated than the waters on any other structure. Results, so

far as they have gone, would appear to indicate that the Parry Lands water correlations can be carried across the Point Fortin, the Pitch Lake and the Los Bajos Structures. The Palo Seco-Erin-Cruse Zone has not been sufficiently investigated to draw any conclusions from the results obtained. Results on this structure appear to follow the chemical variations noted on the other structures.

The Guayaguayare, Barrackpore and Cedros Structures cannot be included in a general treatment of the well water question from a chemical point of view until more evidence is obtained. As far as the other structures are concerned, chemical evidence would lead to the belief that, when the Cruse Zone Waters are fully investigated on the structures where this has not already been done in the south-west of Trinidad, it will be found that the Cruse Waters can be correlated across chemically from one structure to another. (Fig. 9.)

Recent research has demonstrated that salt waters, produced from the upper producing series, equivalent in age to the Lot One Sands, are either free from or only contain a very minute amount of iodine; whereas the salt waters from the Cruse Zone have in general a much higher content.

This is of great economic importance. Many of the problems requiring the analysis of a well water to determine its source are problems where the possibility of letting down a salt water from the upper producing series into the lower producing series, due to imperfect mechanical condition of the well, has to be considered.

It is interesting to note that the water in the Gulf of Paria is free from iodine. The absence of iodine in the Lot One Waters cannot be satisfactorily explained if continuous sedimentation took place from the Cruse Zone to the top of the Miocene, but it is possible that the conditions of sedimentation were more suitable for marine vegetation and the formation of iodine during upper Cruse Zone times.

Testing for iodine content was started late in the well water question, and results have not been fully investigated. One point which, however, stands out from the results obtained is that a water with no iodine content is invariably a Lot One water. It must be noted that the reverse does not hold good—*i.e.*, that all Lot One waters have no iodine content.

So far analytical results have shown that this feature will only be of use on the Parry Lands and Pitch Lake Structures and in the zones of what might be termed the true Lot One type water. It does not hold for the Fyzabad-East structure, and, though it does hold for several waters on the Palo Seco-Erin structure, it is not general.

The chemical results confirm the view previously arrived at that in general only local flooding of the oil-producing sands by salt water is possible. This fact, although it is of great advantage to Trinidad operators, does not obviate the necessity of the chemical investigation. It is of the greatest importance to know if a water which subsequently breaks into a well is due to a salt water being let in owing to some mechanical imperfection or to a salt water in close contact with the oil sand which is being depleted. In any one part of a structure there is no doubt that, given reliable samples, the upper waters can be chemically differentiated from the lower, and this admits of an economic application of the results at any one well.

The main object of the chemical side of the well water question is to conduct a detailed examination of all the salt waters encountered during the early stages of drilling up a structure, so that sufficient data may be obtained to indicate those features which can be used in the correlation of the waters. As a result of this work it should be possible to reduce the analytical tests to include only those which are necessary to identify these chemical features. It is now suggested that the detailed examination of the well waters has been carried far enough and that the analytical work in the future can be reduced to the few simple tests which have been enumerated in the body of the Report under "Suggested Methods of Routine Chemical Analysis of Trinidad Well Waters for Field Use" (pages 6–7). It must, however, be understood that these tests should only be applied to the present proved areas, and that it will be necessary in new areas of development to undertake more detailed analyses until the situation in those areas is understood.

Opinions have been expressed from time to time that the cost of the chemical investigation was not justified by the results from a practical point of view. The lack of results in the past has been due to insufficient knowledge of the problem, and to the absence of general interest and co-operation in its elucidation. It is hoped that this will be overcome by the results published in this Report, which has been put forward as a basis for future work.

DISCUSSION.

The Chairman, in opening the discussion, said that, as Mr. Romanes had stated, the paper was essentially one for detailed study, more especially so because Trinidad in respect of its water problems, as he was afraid also was the case in its geology, appeared to run somewhat contrary to accepted practice. The technological side of the paper would require careful study before he could discuss it in any useful manner; but, on the other hand,

he fully realised its wider aspects, the chief of which was the striking example it afforded of the value of whole-hearted co-operation between companies and companies and between companies and a Government Department. It appealed to him that one of the authors was a Government official and the other the employee of a company. His experience of Trinidad extended to well over twenty years, and he felt that of recent years nothing had been of such use to the industry as the changed attitude among the companies with regard to pooling information and helping one another. In the old days they were secretive, highly suspicious and generally adopted the attitude that under no conditions must others benefit by information which they possessed and by errors which they had committed. That state of affairs had now changed, some credit for the change admittedly being due to the companies, but the larger share being undoubtedly due to the Mining Department and its head. He desired to pay a tribute to Mr. Southwell, and in a less degree to his former collaborator, Mr. Ziegler, for the remarkable way in which they had brought about that co-operation amongst the companies, and the great trouble they had taken in distributing the results of their co-operative work amongst all concerned. Many copies were made of their reports so that every interested company was placed in possession of the complete details. He looked forward to an extension of that policy in order that the industry might be supplied with further useful reports of that nature. He could not conclude his remarks without paying his tribute also to the work of Mr. Romanes.

The Secretary read the following communication that had been received from Dr. Murray Stuart:—

"The authors state: 'The sulphate content of the well salt waters is on the average extremely low; whereas the sea water samples analysed show high sulphate content. This point has been noted and investigated by observers on other fields.' They then go on to explain this observed fact as follows: 'It is generally admitted that the sulphate breaks down through chemical interaction with hydrocarbons and other organic matter with the resultant addition of carbonate to the water.' Is it not generally admitted, on the contrary, that this suggested explanation is a fallacy? The question of the natural reduction of sulphates has been thoroughly investigated by Dr. Edson S. Bastin and his colleagues, with special reference to oilfield waters. The results of their investigations were published in the 'Bulletin of the American Association of Petroleum Geologists,' Vol. X., No. 12, December, 1926. Their finding on this particular point

is summarised by them as follows: 'From this review it may be concluded that thus far no experimental evidence has been obtained of the reduction of sulphates at ordinary temperatures by dead organic matter, although such reductions do take place at high temperature.' They found, on the contrary, fairly conclusive evidence that the reduction of sulphates in oilfield waters belongs to the domain of biological, instead of abiological, chemistry, and actually isolated, prepared a culture of, and identified, the well-known sulphate-reducing bacterial responsible for the phenomena. Unless, therefore, the authors have definite experimental evidence to the contrary, Dr. Edson S. Bastin's pronouncement stands as the authoritative view on the subject.

"It will be remembered that in 1925 Mr. W. H. Cadman attributed to the same suggested abiological interaction of hydrocarbons with sulphate, not carbonate in the oilfield waters, but the origin of hydrogen sulphide in Persian Natural Gas.

"It is worth while remembering that the reduction of $CaSO_4$ by carbon has been investigated by Hofman and Mostowitsch (Trans. A.I.M.E., Vol. XLI., pp. 763-785, 1910). It was found that reduction began at 700° C., and was practically complete at 1000° C. At about these temperatures $C+2H_2O \rightarrow 2H_2+CO_2$ is a well-known chemical reaction, but I venture to suggest that one would hesitate before including it amongst the abiological chemical reactions likely to have taken place in ordinary sedimentary strata."

Dr. J. A. L. Henderson said that having been associated with Trinidad for some time he had read the paper with extreme interest and desired to associate himself with the remarks the Chairman had made in appreciation of the work of the Government officials, in conjunction, of recent years, with the important oil companies, which had effected such advantageous changes in the relationships between the respective parties to the benefit of the industry as a whole. The paper furnished outstanding evidence of the value of such co-operation, because otherwise such results would never have been achieved. Those concerned would have remained in comparative ignorance so far as the possible correlation of waters associated with structures several miles distant was concerned, and a great deal of unnecessary expense and delay would have been caused if similar work had been carried out with the object of identifying and correlating the waters at different horizons. He had been much impressed with the great patience and assiduous labour of those who had investigated the problem, and the discovery of the iodine value seemed to him to be one of the most important results achieved. The comparison between the oilfield

waters and the waters of the sea surrounding Trinidad was remarkable in showing that so little difference in composition existed, as even in the case of such comparatively young sediments some marked difference might be expected. In the older sediments, such as the Carboniferous to as early as the Cambrian, one was accustomed to find certain definite characteristics of "fossil" waters associated with increased depth, but in Trinidad, so far as it was possible to judge from the paper, the depth or thickness of sediments did not seem to have affected the composition of the entombed waters in the same way. He thought an interesting complementary study to that carried out by the authors would be an investigation of the salinity of the sediments themselves. In this connection, he had recently some experimental work carried out during the drilling of an oil and gas well, percussion tools and pure water being used in the work, and had obtained interesting results from sixty-four tests of the comminuted sediments over a vertical horizon of about 1400 ft. A remarkable consistency in the salinity of sediments of different kinds, limestones, sandstones and shales was found, and he suggested that a systematic study carried out on such lines might possibly lead to some enlightenment in regard to the factors affecting concentration of the various constituents of "fossil" waters. He did not by any means regard his tests as conclusive, because the experiment proved that it would be necessary to devise more accurate methods than those used, but the tests clearly indicated that all of the Carboniferous sediments in question contained a certain amount of sodium chloride and other salts. In conclusion, he desired to express his appreciation of the fact that the paper furnished much material on which reliance could be placed as a basis for the practical application in Trinidad of the methods that had been suggested by the authors.

Major T. R. H. Garrett said he had found personally that the examination of the waters in an oilfield was of the utmost value. He made it a practice, even in cases in which opportunities did not occur of examining the waters at the time, to have specimens of the waters bottled in order that they might subsequently be examined with the object of ascertaining whether a water was contained in the sand or whether it had come down from above. The authors had rather stressed the point of the difficulty of obtaining good samples. Personally, he did not think that point was of great importance, because all it was necessary to do was to reduce each solid to a percentage of the total solids and it was then generally possible to ascertain the nature of the water. Even if the water had been contaminated by flush water, it did not make very much difference, because it was generally known what

the nature of the salts in the water were. The authors had also referred to the iodine content in some of the waters examined. Personally, he had found that of great use. In one field in which he was carrying out work there were several different waters which the boring went through, and two of them, one of which gave more trouble to shut off than any other, contained a very large amount of iodine. It was hence of very great value to be able to recognise those particular waters. As he had stated, one of the waters was most difficult to shut off and hence was the one most likely to come down into the well, and if iodine was spotted, those who were carrying out the operations knew immediately the facts that had to be dealt with.

Mr. E. H. Cunningham-Craig said he had always been a great advocate of the study of oilfield waters, partly with the view that certain evidence might be found from a study of them bearing upon the genesis of petroleum. So far he could not say that he had ever found much valuable evidence of that kind in the analysis of waters from oilfields, but this was no doubt due to the fact that as a rule such systematic study had not been carried out as was the case in the present instance. He thought the authors were to be congratulated on the work they had done, particularly as it was the beginning of a very much greater work, which he hoped would be continued systematically throughout Trinidad. There were many points he would like to refer to, the chief one being that the stratigraphical value of the results obtained could not be made very clear until the stratigraphy of Trinidad was a little more carefully worked out. There were a number of points with regard to stratigraphy about which geologists were by no means in agreement, and he thought it was possible that mistakes in stratigraphy might vitiate several of the results that had been given in the paper. For instance, he noticed with regard to the fields of the Pitch Lake, Barrackpore, Guayaguayare and Tabaquite the results were not based upon stratigraphical evidence. That he could quite understand. The areas that had been studied in detail formed in themselves a comparatively small zone in the oil-bearing series, and in that comparatively small zone, where most of the drilling had taken place the oils were to a considerable extent inspissated, that is, oxidised and affected in various ways which were known under the general term of inspissation. In such cases there was certainly reaction between oil and water, both being affected. But when consideration was given to the oils of lower horizons quite a difference was found at once in the amount of salinity, and he gathered that was supposed to be rather extraordinary according to the authors' statement.

Personally, he thought it was fairly simple. In the cases that had been given, for instance, Guayaguayare and Barrackpore, the oils were very much better protected from inspissation and from the interaction of waters. With regard to the question of iodine, he thought it would be found, when the lower horizons in Trinidad, far below the places where most of the production was taking place at the present day, were studied in the same way as the other horizons, a much greater iodine content would be found. Another point that should be kept in view was the analysis of waters from the mud volcanoes. It might not give very good evidence because they were always to some extent flooded by surface water. At the same time, part at any rate of the waters from some of the mud volcanoes had come from a considerable depth and they sometimes gave remarkable results on analysis. He fancied that the darkening of the colour, and a good many of the other characteristics of the waters, was due chiefly to weathering, inspissation, and the interaction of water and oil; but he fancied that would not be found to be so much the case when dealing with the lower and better sealed-up oil sands and their associated waters. It must be admitted that up to the present no very striking results had been obtained, although no doubt locally they were sometimes very useful; but he thought that when the authors had been able to study the whole of the oil-bearing series of Trinidad they would bring out some very striking results which were bound to be useful to the geologist. They would become more and more useful when deeper and deeper drilling took place in that interesting island.

Professor V. C. Illing desired to congratulate the members on having had placed before them a paper full of data on a subject vital to petroleum production. It was a paper which required close study before it could be criticised adequately. Salt water problems engaged a large portion of the attention of the average production geologist, and the speaker was convinced that the movement of such waters was largely responsible for underground oil waste.

The paper contained a number of interesting points which threw light indirectly on the origin of the oil. The occurrence of iodine and naphthenic salts in the water was interesting. He could not agree with a previous speaker that the oils and waters were affected by weathering. In the shallower areas this might be true, but these sands were lenticular, and they were clothed in compact impervious clays and at a depth of one thousand or more feet one could not admit such weathering processes. Water movements in extensive sands which outcrop or approach the surface may induce secondary alterations even at great depths, but such changes must be limited when the porous horizons are lenticular.

It is more likely that the naphthenic salts were introduced during the compaction of the strata which would cause fluid movement into and through those sands, for there was an intimate association of oil and water in these early migrationary phases.

With regard to the low sulphate content, this appeared to be a normal feature in deep connate waters, and though interaction with oils was considered as a possible cause, the speaker felt that biological influences during and after deposition was an explanation of more general application.

It would be unfair to criticise the results of the authors' work on the ground of its failure to find data of real correlative value. They had laid a solid foundation and it was to be hoped that the work would continue, for it was by the accumulation and intelligent application of such data that the problems in Trinidad Geology would receive final solution.

Mr. J. Romanes said he did not intend to attempt to reply to the discussion, as he understood the authors would have the opportunity afforded to them of replying in writing to the remarks that had been made. With regard to the question of the reduction of sulphates by hydro-carbons, although it might be a hackneyed sort of explanation, he thought it was necessary to allow for the possibility of such an action taking place, provided sufficient time was given. After all, a laboratory experiment must be of limited duration, but the geologist could always call on another 100,000 or 1,000,000 years. He had the feeling that, given time, there was a possibility of the reduction of the sulphate from the contact of the hydrocarbons and sulphate water. There was one point which had not been referred to which he would like to mention, because he would be glad of the authors' opinion on the point. The authors laid great stress on the carbonate bicarbonate ratio for different classes of water. Personally, he would have thought that the carbonate bicarbonate ratio was rather a variable factor because the bicarbonates were very ticklish compounds, and he would have thought the amount of bicarbonate was often controlled by the question of temperature and pressure. With the same water under two different sets of circumstances a very different carbonate bicarbonate ratio might be given. He desired, in conclusion, to take the opportunity of associating himself with the remarks the Chairman made with reference to the extreme value of the work Mr. Southwell and Mr. Ziegler had done in Trinidad in bringing about the close co-operation between the different companies and the Government. On behalf of the authors he desired to thank the members for the very kind reception that had been given to the paper.

The Chairman said he was sure it would be the wish of the members to express their appreciation not only to the authors for their excellent paper, but also to Mr. Romanes for the excellent manner in which he had presented it.

The resolution of thanks was carried by acclamation, and the meeting terminated.

The Authors wrote, in reply:

The question of sulphate reduction has been raised by Dr. Murray Stuart. Sulphate is, chemically, a comparatively stable feature and is used on one field for identifying well waters. It is much more stable than the carbonate and bicarbonate feature which has been used in Trinidad for correlation purposes. Any explanation of the derivation of well waters from sea water thus depends on some hypothesis to explain the low sulphate content of well water as compared with the relatively high sulphate content of sea water. The point which the conclusions were intended to convey was that sulphate reduction was generally admitted so that sulphate content was not a stumbling-block in tracing back well waters to sea water.

About the actual method by which the sulphate has been reduced there has been a certain divergence of opinion. This is only natural when one considers that suggestions until recent years have been more theoretical than practical.

Analytical work to solve the question of sulphate reduction was beyond the scope of this paper, and beyond the scope of a refinery laboratory. In touching on the point, several authorities, chiefly Gurwitsch, were considered. In his "Petroleum Technology" he states:

"The opinion has long been held, and is still held by many investigators, that well water cannot contain any sulphates, as these salts would be reduced to sulphides by the petroleum hydrocarbons, as for example,

$$Me_2SO_4+CH_4=Me_2S+CO_2+2H_2O=Me_2CO_3+H_2S+H_2O$$

the hydrogen sulphide being further oxidised by the oxygen of the air to form sulphur as follows:

$$H_2S+O=H_2O+S.$$

Chase Palmer's destructive criticism of the above hypothesis in his "California Oil Field Waters," Economic Geology, Vol. 19, 1924, was considered. He points out that the reaction is endothermic and that, "in absence of proof to the contrary, it may be accepted that sulphates are not reducible to sulphides in oil-field waters." Having made this statement, no constructive theory to explain the low sulphate content of well waters is offered.

We had not, at the time this paper was written, read "The Problem of the Reduction of Natural Sulphates" by Dr. Edson

S. Bastin and colleagues, but were awaiting receipt of a copy which was somewhat difficult to obtain. Now that we have read it, we admit that this paper offers clear evidence of the reduction of sulphates in well waters by bacteria. At the same time Dr. Bastin makes it quite clear that he does not consider the chemical theory a fallacy. Dr. Murray Stuart has rather adopted the attitude of bacteria or nothing. The extract he has quoted would support this attitude, but it does not do full justice to Dr. Bastin as the last sentence from the paragraph quoted has been omitted. This runs as follows:

"Future investigations may, of course, show that some of them can proceed at ordinary temperatures at very slow rates."

The following occurs on page 1296 of the "Bulletin":

"Whether the reduction took place through bacterial action at the time of burial of the sediments, as suggested by Murray's marine studies, or through later bacterial action or through non-bacterial agencies, remains for the present uncertain."

One cannot lose sight of the fact, when dealing with the chemical theory, that it cannot be commenced until the laboratory can reproduce the actual conditions undergone by the water, and prove a negative result. This, as Mr. J. Romanes has stated, will take approximately 1,000,000 years.

With regard to the point raised by Dr. J. A. L. Henderson, the question of the chemical examination of the various sediments was considered by the authors, but was never carried out as the problem appeared to be of purely scientific interest. As has been explained in the paper, the work was carried out for the oil companies who required results of practical rather than scientific utility. The authors' scheme was, as outlined by Dr. Henderson, to test out the sediments for salt and carbonate plus bicarbonate content and to compare the sediments with the waters in contact with them. This could have been done easily and economically in Trinidad where coring is done on a large scale. The examination of apparently dry sediments has been carried out, but only to prove the presence of water.

One point, noticeable in compiling this report, was the wide scope for physical/chemical work of a practical nature on the fields. The tendency has been for the fields to regard the chemist as an unnecessary evil. They are, however, gradually realising the value of research and control work on such questions as mud, cement, etc., and there is no doubt that in the future a chemist or a chemically trained geologist will be an important member of all field staffs.

Major T. H. H. Garrett has raised the point that undue stress has been laid on the necessity of obtaining good samples. It is

possible that in certain fields where there are marked variations in the constituents of the waters from zone to zone that extreme care in sampling is not necessary. In Trinidad, however, where correlation of the well waters is carried out on small variations in the not too stable compounds, carbonate and bicarbonate, it is of the greatest importance.

The carbonate/bicarbonate ratio question raised by Mr. J. Romanes is due to a quick and, unfortunately, incorrect method used in the original to denote carbonate plus bicarbonate, viz., carbonate/bicarbonate. There was no question of ratio between the two, and this has since been changed in the script to carbonate plus bicarbonate. As he points out, the bicarbonates are ticklish compounds which tend to break down to the carbonate. Throughout the paper correlation has been carried out on the carbonate plus bicarbonate content and not on one or other of these compounds. Thus, though part of the bicarbonate may break down, it is still recorded in the carbonate and the sum of the two is sufficient to give the correct correlation of the water. It is interesting to note that during the investigation it was necessary to recheck the bicarbonate content of the waters. Several samples had been kept in the laboratory store for five years in glass bottles, corked, but not sealed, and exposed to the light. It was found that the bicarbonate content of these waters had remained practically unchanged.

Several points have also arisen which were fully dealt with in the original paper. This had to be cut down for insertion in the "Journal," and such data as methods of calculating results, analytical tests, method of recording results, etc., had to be omitted.

In reply to Mr. Cunningham-Craig, the authors wish to point out that the results of Barrackpore, Guayaguayare, Tabaquite and the Pitch Lake Area were based on stratigraphical evidence and a careful correlation of each individual structure, but the precise relationship of these structures to each other has not been determined. Their general relationship is now known, but, owing to local geological arguments of minor stratigraphical differences, it was considered advisable not to tie down a controversial point to an opinion when the majority of the paper is a collation of facts. A considerable amount of coring has been undertaken during the last two years and the evidence obtained has helped to solve many of the debatable points in the geology of the Trinidad Producing Series.

We should like to take this opportunity of thanking Mr. Romanes for his kindness in reading this paper, for the very able way in which he made his selections, and for the kind remarks expressed by the several gentlemen who contributed to the discussion.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

ANNUAL REPORT OF THE COUNCIL, 1928-29.

THE Annual Report of the Council for the Session 1928–29, together with the Accounts for the year ended December 31, 1928, are presented herewith.

The following table shows a net increase of 121 in membership during 1928.

	TOTAL 31.12.27	CHANGES DURING 1928.							TOTAL 31.12.28.
		New	Transferred to.	Resigned	Deceased.	Removed.	Transferred from.	Net gain.	
Honorary Members	10	6	—	—	2	—	—	4	14
Members	467	45	10	5	2	4	—	44	511
Associate Members	334	57	21	6	1	4	10	57	391
Students	115	32	—	2	—	8	19	3	118
Associates	68	19	—	2	—	2	2	13	81
TOTALS	994	159	31	15	5	18	31	121	1115

It is of interest to record that both the number of new Members and the total net increase are in excess of the corresponding figures for any previous year. The election of six new Honorary Members is the result of the powers conferred on the Council at the last Annual General Meeting to appoint occupants of particular positions to Honorary Membership during their term of office.

The Accounts for the year ended December 31, 1928, are presented and Council are glad to state that the Balance Sheet continues to show a satisfactory financial position

The Scholarships awarded by the Institution have been provided for in the Accounts and it has been decided to continue the Awards for the year 1929.

The revenue from Members' Subscriptions shows a satisfactory advance.

A special subscription, contibuted for Research has been added to the Research Fund. A Grant of £75 in connection with Special Research Work was made during the year under review.

In order to deal with the important question of Research to the best advantage and to support as far as possible, individual research, Council have decided to institute a Fellowship of the Institution of the value of £350 per annum and to apply the Research Fund to this object. A Committee of the Council is engaged in drawing up the conditions attaching to the Fellowship. Council have allocated the sum of £150 out of the available balance of revenue to this Fund. The position of the Fund which now amounts to £996 8s. 11d. is shown in the accounts.

The Institution continues to be represented on: The American Society for Testing Materials; the Advisory Board of the Department of Oil Engineering and Refining of the University of Birmingham; the British Association for the Advancement of Science; the British Engineering Standards Association; the Fuel Economy Committee; the Imperial Mineral Resources Bureau; and the Mechanical Warfare Board of the War Office. Representatives of the Institution also attended and took part in the Eighth Congrès de Chimie Industrielle, Strasbourg; the Fuel Conference of the World Power Conference, London; the Second International Conference on Bituminous Coal, Pittsburgh; and the Complimentary Dinner to Col. L. Pineau, Directeur de l'Office National des Combustibles Liquides, Paris.

Ten General Meetings of the Institution were held during the period under review, and the papers read and discussed are set out below:—

One Hundred and Sixth General Meeting, January 10: "The Connection Between Commercial Oil Deposits and Main Structural Features with Special Reference to Asiatic Fields," by L. Dudley Stamp.

One Hundred and Seventh General Meeting, February 14: "Causes of Fire in the Petroleum Industry with Methods of Prevention," by Christopher Dalley.

One Hundred and Eighth General Meeting, February 28: "Flame Characteristics of 'Pinking' and 'Non-pinking' Fuels," by G. B. Maxwell and R. V. Wheeler.

One Hundred and Ninth General Meeting, March 13: "Development Problems in the Exploitation of Natural Gas," by Lieut.-Col. S. J. M. Auld.

Fifteenth Annual General Meeting, March 22: Presidential Address, "The Le Havre Ocean Installation," by Alfred C. Adams.

One Hundred and Tenth General Meeting, April 3: "The Oil Well and Later Developments at Hardstoft, Derbyshire," by Arthur Wade.

One Hundred and Eleventh General Meeting, April 17: "TUBE-STILL DISTILLATION," by C. H. S. Edmonds.

One Hundred and Twelfth General Meeting, May 8: "EXPERIMENTS IN VISCOMETRY," by H. S. Rowell and D. Finlayson.

One Hundred and Thirteenth General Meeting, October 9: "THE ANALYSIS OF CRACKED SPIRITS. THE DETERMINATION OF AROMATIC, OLEFINE, NAPHTHENE AND PARAFFIN HYDROCARBONS," by F. H. Garner.

One Hundred and Fourteenth General Meeting, November 13: "DRILLING AND PRODUCTION METHODS IN THE GREATER SEMINOLE FIELD, OKLAHOMA, U.S.A.," by G. Heseldin.

One Hundred and Fifteenth General Meeting, December 11: "MADAGASCAR AND ITS OIL LANDS," by Arthur Wade.

The six numbers of the Journal published during the year contained the papers read before the Institution, together with the discussions thereon. In addition to these, a number of other papers on various aspects of Petroleum Technology were also published, together with Abstracts of the more important articles appearing in the Technical Press and of Patent Specifications.

The Students' Section has continued its activities and both the London and Birmingham Branches report the holding of meetings and the reading of papers.

The Students' Medal and Prize was awarded to Mr. C. B. Roach and a supplementary prize was presented to Mr. Donald A. Howes. The Scholarships at the Royal School of Mines and at Birmingham University were gained by Mr. C. F. C. Moore and Mr. A. S. Bridgwater respectively.

Dr. A. E. Dunstan, D.Sc., F.I.C., F.C.S., has been unanimously elected as President for the Session 1929-30. Sir John Cargill, Mr. Alexander Duckham, Mr. Arthur W. Eastlake and Mr. Robert Redwood have been unanimously re-elected Vice-Presidents and Sir Richard Barnett and Mr. James Kewley have been unanimously elected Vice-Presidents for the ensuing year.

The Library Committee's Report indicates that increasing use has been made of the Library and that Members abroad appreciate it as a source of information, this being shown by the number of enquiries received by letter.

The Library Catalogue is divided into Sections devoted to Authors, Countries, Subjects, Maps, Technical Bulletins and Memoirs—and is up to date with the exception of Subjects and Maps, which are nearing completion.

The reports received from Trinidad indicate that the new branch of the Institution in that Island, inaugurated on January 1, 1928,

Dr. REVENUE ACCOUNT FOR THE

	£	s.	d.
To Salaries..	1045	11	8
„ Rent, Rates, etc.	445	9	4
„ Printing and Stationery	172	18	7
„ Postage	206	17	5
„ Hire of Hall for Meetings and Expenses of Meetings ..	230	7	4
„ Journals	493	0	7
„ Grants to Branches	102	5	0
„ Income Tax on Interest and Dividends paid without deduction	20	2	0
„ Sundry Expenses	221	5	2
„ Auditors' Fee	10	10	0
„ Students' Prize and Scholarship Fund..	80	0	0
„ Research Fund Account	250	0	0
„ Depreciation of Office and Library Furniture and Library Books	49	0	0
„ Standardization Account	19	13	1
„ Balance at Credit—Carried to Balance Sheet	7	7	2
	£3354	7	4

STUDENTS'

1928.		£	s.	d.
Dec. 31.	To Expenses for the Year	24	16	3
	„ Balance Carried Forward	15	9	3
		£40	5	6

STUDENTS' PRIZE AND

1928.		£	s.	d.	£	s.	d.
Dec. 31.	To Scholarships granted—						
	Royal School of Mines	40	0	0			
	Birmingham University	40	0	0			
					80	0	0
	„ Special Prize				5	0	0
	„ Balance Carried Forward				10	0	0
					£95	0	0

RESEARCH

1928		£	s.	d.
Dec. 31.	To Grants during Year for Research Work	75	0	0
	„ Income Tax	11	17	0
	„ Balance Carried Forward	996	8	11
		£1083	5	11

YEAR ENDED 31ST DECEMBER, 1928. Cr.

	£ s. d.	£ s. d.
By SUBSCRIPTIONS—		
Members	2726 6 6	
Special	451 5 0	
		3177 11 6
„ INTEREST AND DIVIDENDS		170 1 6
„ SALE OF BOOKS		6 14 4
		£3354 7 4

SECTION FUND.

1928.		£ s. d.
Jan. 1.	By BALANCE BROUGHT FORWARD	40 5 6
		£40 5 6

SCHOLARSHIP FUND.

1928.		£ s. d.
Jan. 1.	By BALANCE BROUGHT FORWARD	15 0 0
Dec. 31.	„ REVENUE ACCOUNT	80 0 0
		£95 0 0

FUND.

1928.		£ s. d.
Jan. 1.	By BALANCE BROUGHT FORWARD	801 9 4
Dec. 31.	„ INTEREST	31 16 7
	„ REVENUE ACCOUNT	250 0 0
		£1083 5 11

BALANCE SHEET AS

LIABILITIES.

	£ s. d.	£ s. d.	£ s. d.
To CAPITAL OF THE INSTITUTION, under Bye-Law Section 6, para. 14, viz. :—			
Life Membership Fund—			
As per last Account		413 0 0	
Additions during year		38 5 0	
		451 5 0	
Entrance Fees—			
As per last Account	1475 4 0		
Additions during year	204 15 0		
		1679 19 0	
Profit on Sale of Investment, as per last Account		2 10 0	
Donations, as per last Account		326 5 0	
			2459 19 0
,, STUDENTS' PRIZE AND SCHOLARSHIP FUND			10 0 0
,, RESEARCH FUND ACCOUNT			996 8 11
,, STUDENTS' SECTION FUND			15 9 3
,, SUBSCRIPTIONS (MEMBERS) PAID IN ADVANCE			237 6 0
,, SUBSCRIPTIONS (JOURNAL) PAID IN ADVANCE			204 10 6
,, SUNDRY CREDITORS			302 19 10
,, REVENUE ACCOUNT—			
Balance as at 31st December, 1927 ..		1668 14 8	
Less: 1927 Subscriptions in arrear written off		51 19 6	
		1616 15 2	
Add: Subscriptions prior to 1927 written off and now collected		27 6 0	
		1644 1 2	
Add: Credit Balance for year, as per Revenue Account		7 7 2	
			1651 8 4
			5878 1 10

Members of Council { ALFRED C. ADAMS. F. W. BLACK.

We have examined the above Balance Sheet with the books of the Institution are of opinion that such Balance Sheet is properly drawn up so as to exhibit a best of our information and the explanations given to us and as shown by the

3, FREDERICK'S PLACE,
OLD JEWRY, LONDON, E.C.2.
1st February, 1929.

AT 31ST DECEMBER, 1928.

ASSETS.

	£ s. d.	£ s. d.
By INVESTMENTS AT COST—		
(1) On Account of Capital—		
£664 6 6 London County 3% Consolidated Stock	481 10 6	
£1025 0 0 5% War Loan, 1929/47	966 13 1	
£150 0 0 Birmingham Corporation Stock 6%	146 16 0	
£650 0 0 3½% Conversion Stock	505 7 0	
£100 0 0 Wigan Corporation Stock 5% ..	99 14 11	
£160 0 0 New South Wales 5% 1945/65 ..	158 7 0	
		2358 8 6
(Note: Market price of above Investments at 31st December, 1928, was £2,418 18s. 11d.)		
(2) On Account of Revenue—		
£1100 0 0 5% War Loan, 1929/47 .. .. (Market value, £1130 5s. 0d.)		1118 3 6
(3) On Account of Research Fund Investment Account—		
£500 0 0 5% War Loan, 1929/47 .. .. (Market value, £513 15s. 0d.)	510 8 3	
Cash on Deposit with Bank	347 17 8	
		858 5 11
„ OFFICE AND LIBRARY FURNITURE (excluding presentations)—		
As per last Account	459 14 3	
Additions during year	21 10 0	
	£ s. d.	
Less: Sales during year	8 10 0	481 4 3
Depreciation	22 11 0	
		31 1 0
		450 3 3
„ LIBRARY (BOOKS) (excluding presentations)—		
As per last Account	176 8 1	
Additions during year	36 5 10	
	212 13 11	
Less: Depreciation	26 9 0	
		186 4 11
„ SUBSCRIPTIONS (1928) OUTSTANDING at date and considered collectible..		110 15 6
„ SUNDRY DEBTORS AND PAYMENTS IN ADVANCE ..		118 13 10
„ CASH ON DEPOSIT		200 0 0
„ CASH AT BANK AND IN HAND		477 6 5
		£5878 1 10

and having obtained all the information and explanations we have required, we true and correct view of the state of the Institution's affairs, according to the books of the Institution.

PRICE, WATERHOUSE & CO.

is making satisfactory progress. The Rumanian and Persian Branches also report considerable progress and the Council have every reason to be satisfied that the high standard required by the Institution is being maintained by these three branches.

The Members of the Standardization Committee have continued to devote considerable time to the production of the new edition of "Standard Methods of Testing Petroleum and Its Products." Although it was found impossible to issue the book during 1928, the Committee have pleasure in reporting that it is now in the printer's hands and will shortly be available for distribution. The new book, which contains full particulars of new and revised methods for the testing of petroleum and its products, will prove a valuable addition to petroleum literature.

The Tenth Annual Dinner, held at the Connaught Rooms on October 3, 1928, was attended by nearly 200 Members and guests.

The Council deeply regret to announce that five Members of the Institution have died during the year, namely, Dr. F. Mollwo Perkin, G. H. Sargent, Admiral Sir Edmond Slade, R.N., Sir Aubrey Strahan, and L. L. Wrathall.

Facilities for the holding of Meetings have continued to be afforded by the Royal Society of Arts at their House, and the Council desire to record their thanks and appreciation. The Chemical Industry Club is also thanked for its courtesy in making arrangements for the Members of the Dinner Club to dine at its premises.

The Council desire to express their sincere thanks for services rendered by Sir William Plender, Bart., G.B.E., Honorary Treasurer; Messrs. Ashurst, Morris, Crisp & Co., Honorary Solicitors; Messrs. Price, Waterhouse & Co., Auditors; Dr. A. E. Dunstan, Honorary Editor; Mr. George Sell, Assistant Editor and Secretary, Standardization Committee; and Commander R. E. Stokes-Rees, R.N., and his Staff.

The Auditors retire and, being eligible, offer themselves for re-election.

By Order of the Council,

ARTHUR W. EASTLAKE,
Honorary Secretary.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

SIXTEENTH ANNUAL GENERAL MEETING.

THE SIXTEENTH ANNUAL GENERAL MEETING of the members of the Institution of Petroleum Technologists was held at Aldine House, Bedford Street, Strand, London, on Tuesday, March 19th, 1929. The retiring President, Mr. Alfred C. Adams, was in the Chair.

The Secretary (Commander R. E. Stokes-Rees, R.N.) read the Notice convening the meeting, together with the Auditors' Certificate.

The Secretary then read the Minutes of the last Annual General Meeting, which were signed by the President as correct.

The Secretary read the result of the Ballot for the Council, stating that the three retiring members, Mr. T. Dewhurst, Mr. A. Beeby-Thompson and Mr. W. Sutton had been re-elected, together with Professor A. W. Nash, the new member.

The President laid on the table the list of members elected and transferred during 1928.

The Secretary read the list of new members elected since the last General Meeting.

Members.—George William Dunkley, James Taylor Guthrie, I. J. F. Reydon, Hans Tropsch.

Transference to Member.—Robin Roy Redgrave.

Associate Members.—William Hannah Chalmers, Hal Begtup Coats, Robert Kelso Dickie, Robert Scott Wishart, Reginald Frank Stuttle, Edward Ernest Upton.

Students.—George Bourkoff, Henry George Follenfant, Norman Malcolm Johnson, Alexander Reid.

Associates.—Robert Edwin Goldsbrough, Norman Dennis Rothon.

The President then presented the Annual Report of Council for 1928-9, and moved its adoption. He said that the Report had been circulated to members, and he presumed they would agree to take it as read. (Agreed.)

The Report showed that the Institution continued to make satisfactory progress, and indeed each year seemed to demonstrate that its influence was more widely recognised and its activities more generally appreciated. The membership had again shown a gratifying advance. The net increase for the year of new members was 121, equal to more than 12 per cent. of the membership at the end of 1927. This figure included only those who had taken up their membership—that is to say, those who were paying their subscriptions at December 31st; but in addition there were a number of new members who by reason of residence abroad had not sent in their subscriptions, and these, for the time being, were not taken into account. Further, there were 24 applications for election remaining to be dealt with at the end of the year. These figures, he thought, were sufficient indication that as regards membership the Institution was in a sound and even a robust condition.

The Accounts for the year would be explained by the Chairman of the Finance Committee, Sir Frederick W. Black. The scholarships awarded by the Institution were being continued, and he hoped that members might regard these as a regular feature which was not likely to suffer interruption. The Research Fund had been engaging the serious attention of the Council. Hitherto the applications for grants from this Fund for purposes of specific research had been, and perhaps must necessarily be, on a small scale, and somewhat strikingly disproportionate to the large allocations formerly made in the budgets for these purposes. After closely examining the situation with the experience of the last few years, the Council had come to the conclusion that useful and independent research could most effectively be supported by establishing a Fellowship of the Institution of the value referred to in the Report, and it was hoped that this would meet with the approval and support of the members.

The branches of the Institution continued to make excellent progress. The Rumanian branch had some 80 members, and the Persian branch nearly as many. It would be noticed that the new branch in Trinidad was established on January 1st, 1928, and was now a going concern; it numbered some 35 members.

The work of the Standardization Committee in revising "Standard Methods of Testing Petroleum and Its Products" might be said to be at an end for the time being. The last corrections of the final proofs were in hand, so that the issue of this valuable book might be looked for in a comparatively short time. He had heard that afternoon that it was quite likely that the book might be ready for issue at the beginning of May.

The thanks of the Institution were due to the members of the Standardization Committee who had carried out a most arduous

piece of work of inestimable value to the petroleum industry. (Applause.) A great deal of work in this connection had necessarily devolved upon Mr. George Sell, who had acted as Secretary to the Committee, and he desired on behalf of the Council to acknowledge its indebtedness to him for the careful and painstaking work he had put in. (Applause.)

With regard to the Journal, under the very able editorship of Dr. A. E. Dunstan, assisted again by Mr. Sell, the publication had maintained its level of excellence and its outstanding value as a work of reference. The demand for the Journal was ever increasing.

In conclusion, he thought it would be agreed that the Institution had done a great deal of excellent work, and that so far as the activities of the Council were concerned outside the question of finance, which Sir Frederick Black would deal with in a moment, it was in a very sound and substantial position.

Mr. A. E. Chambers seconded the adoption of the Report.

Questions were invited, but none were forthcoming, and the Report was adopted unanimously.

The President next moved the adoption of the Balance Sheet and Accounts for 1928.

Sir Frederick W. Black, Chairman of the Finance Committee, in seconding, said that it was known to the members that during the two years of Mr. Adams' Presidency, the Chairmanship of the Finance Committee, ordinarily held by Mr. Adams, had devolved upon himself, but Mr. Adams had been in as regular attendance at the Finance Committee as if he had been its Chairman.

The Accounts spoke for themselves, with the notes in the Report. The situation was very satisfactory. Last year, owing to the fact that £400 was allocated to the Research Fund, and several big items of expenditure had to be met which were not of annual occurrence, there was a deficit of about £248. This year the Committee had striven to make ends meet, with the consequence that there was a small credit balance. It would have been £150 larger, but the Council decided to endow the Fellowship by £150 beyond the £100 that had already been appropriated. The subscriptions had gone up by some £270, and he thought it could be said that the money of the Institution had been well and worthily spent. An extra sum of £50 had been paid to the branches abroad, all three of which were doing much good work. The Journal was costing a little more. Six Journals were published in 1928, as in 1927, but 9000 copies were printed in 1928 as against 8600 in the previous year. The cost of production was necessarily larger,

but, fortunately, revenue from sales and advertisements had increased, and the net cost of the Journal for the Institution in 1928, taking all the costs of production into account, and deducting sales and advertisements, was £493, as against £370 in the previous year. He was sure the members agreed that this could be regarded as money well spent. It would be seen from the Report of the Research Fund that the balance to be carried forward was £996. The President had already stated that the scholarships were costing the same amount and were likely to be continued. There were certain increases in postage and other current expenses of that sort, but generally the figures were much as in the previous year. There was an item of £19 on the Debit side of the Revenue Account put down to Standardization. This was due to the fact that there were always certain standing expenses for the work of the Secretary of the Standardization Committee in the production of the new book, but which were normally covered by the sales of the old book. The Institution had very properly announced well beforehand that a new book was coming out, and it followed naturally that no one wanted to buy the old book, but were waiting until they could obtain the new one, and therefore the final sales of the old book had fallen off. But when the new book was issued he believed that everyone would rush to buy it. He might mention that advertisements of a specially selected character would be introduced, and the new book was much larger than the old.

It was going to be a really up-to-date publication, and he hoped that members would tell their friends, and hurry up and make sure of getting a copy as soon as it came out. It was extremely gratifying to him to be able to give this satisfactory account of the finances of the Institution, and he seconded the adoption of the Balance Sheet and Accounts.

This motion also was carried unanimously.

The Secretary then read the Annual Reports of the London and Birmingham branches of the Students' Section.

London Branch.—At the 31st December, 1928, the Student members of the Institution numbered 118. During the year under review there were in all 32 new members, to whom a hearty welcome is extended, and 19 members were transferred, 8 removed and 2 resigned.

At the Fifth Annual General Meeting in February, 1928, the following were elected to serve on the Committee: Messrs. S. E. Coomber, J. E. Duckham, G. C. F. Greant, C. E. Hobley and M. Kamenetsky. Mr. Duckham was subsequently elected Chairman; Mr. Kamenetsky, Vice-Chairman; Mr. Hobley, Hon. Secretary; and Mr. Greant, Hon. Excursion Secretary.

During 1928 seven meetings were held :—

January : "Notes on Pipe-Lines and Pumping Plants," by C. Dalley.

February : "The Development of the Modern Drilling Rigs," by H. C. H. Thomas.

March : "Air and Gas Lift for Oil Wells," by C. B. Roach.

May : "The Pechelbronn Field," by E. L. Leites.

October : "The Essential Qualities of Various Petroleum Products," by W. B. Rowntree.

November : "An Outline of Petroleum Distribution," by W. M. Hurrell.

December : "The Apprentice Driller," by J. E. Duckham.

An excursion was arranged in February to Messrs. Van de Berghs, Ltd., Margarine Works at Fulham, and the attendance was quite gratifying.

At the meetings during the past year the attendance on the whole has improved, and it is hoped will continue to do so in 1929.

On the recommendation of the Committee, the Council of the Institution granted permission for tea to be served before Student Meetings at Aldine House. This was successfully introduced at the May meeting, under the kind supervision of Miss Despard, to whom the Section is extremely grateful.

Several Student papers were entered for the annual Medal and Prize offered by the Institution. The Council awarded the prize to Mr. C. B. Roach for his paper on "Air and Gas Lift for Oil Wells." There has been a lamentable lack of Student papers this Session, and it is sincerely hoped that more will be forthcoming during the coming Session.

The Committee takes this opportunity of thanking the senior members of the Institution who have attended meetings and those who have assisted in furthering the activities of the Students' Section throughout the year.

(Signed) C. E. Hobley, Hon. Secretary.

(Countersigned) Alfred C. Adams, President.

Birmingham Branch.—The Committee has pleasure in presenting the Sixth Annual Report for the year ending 31st December, 1928.

The average attendance of members at the meetings has been very satisfactory, being over 95 per cent., in addition to which many visitors have attended the meetings.

During the year six meetings were held at which the following papers were read :—

January 24th : "Shutting-Off Water in Wells," by H. N. de Wilde.

February 14th : "Natural Gas," by James Kewley.

March 13th : "Power Alcohol," by R. G. Ffoulkes-Jones.

October 23rd : "Oil in Iraq," by G. V. Davies.

November 20th : "The Use of Clay Adsorbents in Petroleum Refining," by K. E. Humphrey.

December 4th : "A Symposium on the Origin of Oil."

On February 10th, a visit was paid to the Oil Well Engineering Co., Cheadle Heath, where a very interesting tour of the works was made under the guidance of Mr. J. Cuthill and his colleagues. The visitors were afterwards entertained to lunch and tea.

A Supper was held at the Royal Restaurant on October 30th, at which 26 members were present.

At the Annual General Meeting, held on March 13th, the following officers were elected for the 1928-9 Session : Chairman, Donald A. Howes ; Vice-Chairman, K. E. Humphrey ; Committee, Messrs. Bridgwater, Ford, Harris and Wiggins. Mr. N. Johnson was subsequently co-opted to represent the first year students. Hon. Secretary, L. P. Timmins.

The Institution Scholarship for the year has been awarded to Mr. A. S. Bridgwater.

The Committee wish to express their appreciation of the grant of seven guineas which has enabled refreshments to be served before the meetings and has defrayed the cost of the lanternist and other incidentals.

(Signed) LAUNCELOT P. TIMMINS, Hon. Secretary.

(Countersigned) ALFRED C. ADAMS, President.

Mr. C. W. Wood proposed, and **Mr. W. J. Wilson** seconded, the re-election of Messrs. Price, Waterhouse and Company as Auditors, at a remuneration of 10 guineas per annum. This was carried unanimously.

The President (Mr. Alfred C. Adams) said that this concluded the ordinary business for which the meeting had been called, and he had now the very pleasant duty of inducting his successor in the Chair. Before proceeding, however, he desired to say a few words on the position of the Institution by way of completing the information given in the Report, and to offer one or two personal reflections on certain aspects of its work. The history of the Institution since its inception had been a record of steady growth.

Since the termination of the War it had advanced rapidly both in size and importance, and its growth was the very natural result of a well recognised need which it filled in the petroleum industry. It had grown because of the determined activities of its members and because of the very hard-working Council which had energetically followed up the objects for which the Institution existed. There was no doubt that by these means the Institution had won a position which entitled it to be recognised as a factor of imperial importance.

Perhaps the growth of the Institution could best be visualised by the fact that since the end of 1922 the membership had doubled, and the income from membership subscriptions had been more than doubled. There were now 1140 members of all grades, as against 561 members at the end of 1922. The members really numbered more than 1140, but, for reasons he had already explained, certain members were not yet actually counted as being in the list. As a record of achievement in the short period of six years these figures were remarkable. In the same way the Journal had won a position of high repute amongst scientific publications. The demand for the Journal outside the membership had gone up from 983 copies for the year 1922 to 2137 for 1928—an increase of 117 per cent. This increase reflected, he thought, the interest taken in the Institution by the scientific world, and it certainly pointed to the high estimation in which the Journal was held on all sides as a manual of reference. It had now become necessary to print 1750 copies of each number, and of this number much more than half were sent to members and others residing and carrying on their duties in parts of the world outside Great Britain. It had been pointed out that to many members, who by reason of residence abroad were unable to attend the regular meetings, and join in the discussions, the Journal was of the first importance, since it in fact represented about the most valuable return the Institution could give these members for their support. Many highly important papers were published in the Journal on a wide range of subjects connected with the petroleum industry, but it was difficult at all times to ensure that the real needs of those who were carrying out special and varied work in far off regions were entirely satisfied. At the same time, every endeavour should be made, and was made, to obtain papers and information on subjects which covered as completely as possible the whole range of the problems confronting the worker who was engaged in the practical winning of oil and its handling. The onus of this work had fallen upon Dr. A. E. Dunstan, who had acted as Hon. Editor of the Journal for the last eight years, and to whom must be ascribed the credit for a very large measure of its success. He felt that the whole-hearted

thanks of the Institution were due to him for the enormous amount of hard work he had placed at their service. Certainly the success that had attended his efforts was gratifying to them all. (Applause.)

The financial position of the Institution had been explained by Sir Frederick Black, who, during the last two years, had watched over the finances in the able and thorough way which so distinguished him. They would agree with him that the financial position was sound.

He would like to say a word to the Students, of whom there were 118. The reports of the Students' Section submitted showed that they had been very active, and that both in the London and Birmingham branches meetings had been held regularly at which papers had been read. Last year three of the Students sent in papers in competition for the Students' Medal and Prize. He liked to think that they could do better than that, and he wanted to see opened up by the Students a wider field of competition. Whilst as an Institution they realised that the future depended upon youth—that was to say, the Student of to-day—and that youth would be served, he would like to suggest to the youth who was being served, and served, he thought he could say, very well by that Institution, that he in his turn was not making sufficient effort at the moment to serve the Institution. It was encouraging to find, as they had learned that evening, that the Students themselves appreciated the desirability of making greater efforts in this direction. It was quite possible that if half, or even a quarter, of the Students set to work to prepare papers for the competition, there would still be only one prize, but it would afford evidence of the right kind of effort and of service on the Institution's behalf, and certainly no less service to the Students themselves. The prize *per se* was not everything. What mattered most was that very necessary effort of application and painstaking study of a particular subject which could not but help the writer of such a paper. It might contain some observation by a young mind which would lead a senior member of the Institution on to a special line of thought. It was in this way that the seniors learned from the juniors.

Before closing these remarks he wanted to mention an item of the Institution's work as to which in the past but little had been said. The Library of the Institution was an important item in its equipment. It included on its shelves a representative collection of books on the technology of petroleum, and a vast number of bulletins and bound periodicals which during the period of which he had been speaking, had increased in number by 50 per cent. The high estimation in which the Library was held might be appreciated from the large number of inquiries almost daily received

from members and others, and from Government and other bodies in this country and abroad, who sought, and readily obtained, the information they required from this source. A complete card catalogue was in existence, which was conveniently arranged under three sections, namely, Countries, Subjects and Authors. Some idea of the value placed upon the resources of the Library could be gained from the fact that during 1928 the personal visits from members and others seeking information upon matters in which they were specially concerned was 546, and the number of such visitors had been consistently increasing year by year. The Library staff had also dealt with over 350 telephone inquiries, and quite 300 letters were written during the year concerned with the same matter. There was, in fact, a richly endowed and efficiently managed instrument, ready to hand of the members and other seekers for information, who, he was glad to say, appeared to appreciate more and more the advantages it offered.

Lastly, he wished to tender to the members of Council, with whom he included the Past-Presidents and Vice-Presidents, his sincere thanks for their unfailing patience and help during his term of office. He wished, also, to thank the Secretary, Commander R. E. Stokes-Rees, and his Staff, for their hearty co-operation at all times. His duties as President had brought him into close association with the Secretary, and he could speak from experience and with gratitude of the zealous way in which he had always supported him in conducting the work of the Institution.

It was now his privilege and his very great pleasure to ask the members to welcome their new President. Dr. Dunstan was well-known to them all as a distinguished scientist and a very earnest and ardent worker in the petroleum industry. He was more intimately known to those in the inner circle of the Institution for his record of very splendid service which he had rendered to that body, and which was quite fresh in their minds. He asked Dr. Dunstan to take the Chair as President of the Institution.

Dr. A. E. Dunstan, the new President, then took the Chair amid loud applause. He said that his first duty was rather a mournful one. It was to announce that the Council had heard that day of the death of Dr. Paul Dvorkovitz. Many members present would remember Dr. Dvorkovitz at the meetings of the Institution, and they would recollect his sons were members of the Institution. Members would desire to tender them their most sincere condolence. (Hear, hear.)

His particular privilege that afternoon was to propose a vote of thanks to Mr. Adams. Before doing so he thought he was perhaps entitled to thank the Council, and through them the members, for the honour conferred upon him in electing him to the Presidency,

and also to venture upon a few reminiscences. He remembered, late in 1914 or early in 1915, being invited by the late Sir Boverton Redwood to join the Institution. In reply he told him that already he was a Fellow of five chemical societies, and as far as he could see there was no particular advantage in joining that body. The reply he got was that the Institution was not a chemical society, it was a collaborative society of chemists, physicists geologists and engineers, all concerned in the exploitation of petroleum technology. A few years later, in 1919, Sir Boverton asked him to take over the control of the Journal, then in the very able hands of Mr. W. H. Dalton, and he accepted with the proviso of a year's apprenticeship with Mr. Dalton. That year passed, and for nine years it had been his great privilege to put before the members as fully and accurately and clearly as one could an account of the progress of their science. In those early days the Journal was a slim volume of about 300 pages. Members were aware of its bulk to-day. At the time of which he was speaking it contained merely reprints of the various papers read before the Institution. To-day it contained those same papers, contributed articles, reviews, and, most important of all, a very excellent set of abstracts of contemporary scientific work. He thought it could be fairly said that the Journal had kept pace with the growing needs of the Institution. They could not be accused of letting it lag behind. At the same time, the Publication Committee would welcome very heartily more funds so that they could get ultimately a monthly Journal. He personally would not be satisfied until their Journal came out month by month. In a recent visit to the States he had had the pleasure of hearing very complimentary views about the Institution and its Journal, and the opinion was offered in many quarters that there might be even greater spheres of influence for it than existed at present. He looked upon his election as a vote of thanks and appreciation to the Journal of the Institution. He would like to say a word about the actual running of the Journal.

It was his privilege in the early days of the Institution to form a Publication Committee, and since that time he ventured to say that there was no Committee of the Council that had done more hard or more valuable work. Every paper that came forward had to be refereed, and in most cases the Publication Committee undertook that very responsible work, with the result that every paper was vouched for and hence the necessary standard could be maintained. He wished to express his personal appreciation of the work of Mr. George Sell. For several years now he had been his right-hand man, and as a result of his efforts the Institution had a Journal in which accuracy was the keyword and misprints

very rare. He wished, also, to thank Mr. W. H. Thomas, who had taken over the arduous business of arranging the abstracts, and had done it with his customary thoroughness. One of the drawbacks of his own election as President was that his work on the Journal would necessarily be curtailed, but he could only hope that he might follow the example set by the late President, and at the end of his period of office again take up the reins of the Journal. He could say this with regard to the Publication Committee, that the issue of the Journal was not looked upon as a matter of form or routine, but really and truly every member regarded his work thereon as a pleasure.

It was now his duty to ask the members to record their appreciation of the work of Mr. Adams. The speaker was very much impressed two years ago when Mr. Adams said that he was rather inclined to represent a branch of petroleum technology that appeared to have been overlooked in the past, namely, the branch which dealt with the financial and administrative side. But he ventured to submit that apart from Mr. Adams' known supremacy in that department, he also ranked as a petroleum technologist. The speaker knew him away back in 1915, when various confidential operations were in progress in his refinery, and he could assure the members that there were very few men who had a better all-round knowledge of petroleum production and refining. For many years Mr. Adams had controlled the spending department of the Institution, and the sound financial position of the Institution to-day was a testimonial to the work he had done.

The Institution was very fortunate in that its Past-Presidents did not leave it. They represented the strongest element in the Council to-day, and he expressed a fervent desire that Mr. Adams would long participate in their deliberations, and he asked the members to accord a very hearty vote of thanks to him for his services.

The vote of thanks was carried with loud applause.

Mr. Alfred C. Adams thanked the new President very heartily for the kind expressions which he had used in proposing the vote of thanks, and the members for their cordial reception of them. He had listened attentively to what the President had said about the way the Institution was supported by those who had passed the Chair. He had himself commented upon that very gratifying fact, and he hoped that he would be able to do quite an amount of work in continuing the service he had been able to render to the Institution. Certainly no efforts on his part would be spared to give the President every assistance that he needed. He had only to call upon him, and he would do his best. (Applause.)

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Mr. W. H. Howe desired to ask a question. First, he wanted to endorse all the appreciative remarks which had been said about the work of the Council, and particularly about the Secretary. Commander Stokes-Rees. But he wanted certain information. He was concerned with the question of the membership of the lubricating oil and grease blenders in different parts of the country. There was a big field there from which the Institution membership might be increased. He had a number of applications for membership on his desk, but he could not get them through, owing to the fact that nominators were not available in the part of the country where these people lived. It was all very well for those in London, but there was some difficulty in other parts of the country. Was there any way in which the Institution could assist by bringing in the men attached to the lubricating oil trade—the genuine blending trade of the country—which comprised men of practical knowledge of the lubrication side? Possibly many of them could be brought into the Students' section.

The President said that that matter could be very simply dealt with. There were in the country some 600 members of the Institution, and if it was not possible to get into direct contact with a member in the locality, it was more than probable that somebody in London attached to the firm with which the applicant was connected would be willing to sponsor him.

Mr. Howe pointed out that there must be personal knowledge of the applicant.

The President agreed that that was the rule of the Institution. This concluded the business and the proceedings then terminated.

INSTITUTION OF PETROLEUM TECHNOLOGISTS.

TRINIDAD BRANCH.

ANNUAL REPORT, 1928.

THE question of forming a Trinidad Branch of the Institution of Petroleum Technologists was discussed at a meeting held at the Paramount Hotel, San Fernando, on December 10th, 1927.

On January 25th, 1928, a further meeting of members of the Institution of Petroleum Technologists was held at the Mines Office, San Fernando. At that meeting the Chair was taken by Sir Thomas Holland, and there were twelve members present. A Committee consisting of Messrs. A. G. V. Berry, A. P. Catherall, W. J. C. Cooke, A. F. Dabell, J. S. Parker, and G. H. Scott was elected, and was empowered to draft By-Laws for the Local Branch for submission to London.

The first Committee meeting was held at Philippine on February 1st, 1928, when Mr. A. F. Dabell was elected Chairman, and Commander H. V. Lavington was co-opted by the Committee and elected Honorary Secretary. At this meeting the proposed By-Laws were drafted for submission to London, and it was decided that the Council be asked that official recognition be granted to the Trinidad Branch of the Institution of Petroleum Technologists.

On May 2nd, 1928, a letter was received from the Secretary of the Institution stating that the Council had sanctioned the formation of the Trinidad Branch and approved of the proposed By-Laws. The Council also granted a Foundation Grant of £5 and a monthly allowance of £2 and dated the formation of the Branch as from January 1st, 1928. One complete set of the Journal to date, one copy of the Empire Motor Fuels Report, one copy of "The Petroleum Industry," and one copy of "Standard Methods of Testing Petroleum and its Products" were sent by the Council, on loan, for the use of the Trinidad Branch.

An Extraordinary General Meeting was held on October 31st, at which a resolution was passed changing the date of the Annual General Meeting from the last Wednesday in November to the last Wednesday in February of each year.

INSTITUTION OF PETROLEUM

CASH ACCOUNT FOR THE YEAR

RECEIPTS.

		$
May 26.	To Foundation Grant (£5) and monthly allowance from London for Jan.-May, 1928 (5 months @ £2 = £10) = £15 ..	71.58
June 25.	„ June Allowance from London	9.32
July 17.	„ July „ „ „	9.32
Aug. 27.	„ August „ „ „	9.32
Oct. 12.	„ September „ „ „	9.32
„ 24.	„ Allowance from London for quarter ended 31st Dec., 1928	28.52
Dec. 31.	„ Registrations to Local Branch	18.00
		$155.38

Audited and found correct,

F. MIDDLETON.
D. W. WALSH.

27/2/29

ACCOUNT OF INCOME AND EXPENDITURE

	$
To Cheque Stamps	1.00
„ Stationery	20.89
„ Postages	4.69
„ Stenographer—7 Papers @ $10.00	70.00
„ Exchange	1.82
„ Balance—being Excess of Income over Expenditure	58.80
	$157.20

BALANCE SHEET AS AT

Profit and Loss Account—

Excess of Income over Expenditure for the year ended 31.12.28 ..	$58.80
	$58.80

TECHNOLOGISTS (TRINIDAD BRANCH).

ENDED 31ST DECEMBER, 1928.

PAYMENTS.

		$
June 9.	By Cheque Book	1.00
„ 23.	„ Payment to Stenographer for March, April and May ..	30.00
July 13.	„ Yuille's Printerie	18.85
„ 13.	„ Payment to Stenographer for June	10.00
„ 13.	„ One Receipt Book	.36
„ 13.	„ Postage to 30.6.28	3.29
Aug. 16.	„ Payment to Stenographer for July	10.00
Sept. 12.	„ „ „ „ „ August	10.00
Nov. 3.	„ „ „ „ „ October	10.00
	„ B.C.O. for Minute Book and Stationery	1.68
	„ „ Postage Stamp a/c to 31.12.28	1.40
Dec. 31.	„ Balance at Bank	58.80
		$155.38

BANK RECONCILIATION STATEMENT.	$
Balance as per Pass Book	47.53
Add: Deposit credited after 31.12.28	11.27
Balance as per Cash Book	$58.80

FOR THE YEAR ENDED 31ST DECEMBER, 1928.

	$
By Foundation Grant from Institution	24.00
„ Monthly Grant from Institution—12 months @ £2 per month ..	115.20
„ Members Registration Fees—18 Members @ $1.00	18.00
	$157.20

31ST DECEMBER, 1928.

Cash at Bank	$58.80
	$58.80

INSTITUTION OF PETROLEUM TECHNOLOGISTS (TRINIDAD BRANCH).

H. LAVINGTON, *Hon. Secretary.*

During the year eight ordinary meetings were held, at which the following papers were read and afterwards discussed :—

February 29th : " Coring Practice," by Mr. G. H. Scott.

March 28th : " Cementing," by Mr. F. J. Shaver.

April 25th : " Recovery of Oil by Air and Gas Lift," by Mr. W. G. Payne.

May 30th : A discussion was held on a Paper entitled " Adaptation of Deep Well Drilling Methods in the Ventura Avenue Fields," which had appeared in " Oil Field Engineering " and " Oil and Gas Journal."

July 4th : " Well Waters of Trinidad," by Messrs. J. S. Parker and C. A. P. Southwell.

July 25th : A discussion was held on the Paper read on July 4th by Messrs. J. S. Parker and C. A. P. Southwell.

August 29th : " Sanitary and Labour Problems from a Medical Standpoint in the Tropics," by Dr. R. Henry.

October 31st : " Some Phases of Cracking," by Mr. S. M. Blair.

A prominent feature of the ordinary meetings was the keen discussion on all technical points which arose in the Papers read.

The average attendance at these meetings was thirty-three members and friends.

The members of the Branch have to thank the members of the Apex Club, the Trinidad Leaseholds' Forest Reserve Club, and the Trinidad Leaseholds' Pointe-a-Pierre Club for the use of their Clubs for the Ordinary meetings.

On December 31st, 1928, nineteen members of the Institution had registered as members of the Trinidad Branch.

H. V. Lavington, Hon. Secretary.

The Replaceable Bases in the Shales and Clays Overlying Petroliferous Strata.*

By E. McKenzie Taylor, M.B.E., Ph.D., D.Sc., F.I.C., School of Agriculture, Cambridge.

In a previous paper[1], the possible bearing of base exchange on the formation of petroleum was discussed. It was shown, as the result of an examination of a small number of specimens, that the shales and clays overlying the oil-bearing sands in certain areas had undergone base exchange with solutions of sodium chloride resulting in the formation of sodium clay. It was shown, further, that the sodium clay thus formed had been subjected to hydrolysis in freshwater which had resulted in the formation of a continuously alkaline medium suitable for the decomposition of organic matter by bacteria. It was demonstrated in the laboratory that the decomposition of organic matter by bacteria was a continuous process in the alkaline medium produced by the hydrolysis of sodium clay, since the continuous alkalinity prevented the accumulation of toxic acid products. It was also shown that the shales and clays containing the sodium clay were impermeable to both liquids and gases and, hence, that the decomposition was carried out under anærobic conditions and the products of the decomposition were prevented from escaping. It was pointed out that, from the geological evidence, the majority of the shales overlying oil-bearing strata must have undergone base exchange with solutions of sodium chloride. It is rare, however, to find in the literature on the subject evidence that the sodium clays thus formed have been subjected to the action of freshwater. An examination of an extensive series of shales is necessary, therefore, to determine whether the sodium clay in the shales has been subjected to hydrolysis. The results recorded in the present paper were obtained from the examination of shales and clays in three oilfields : Trinidad, Mexico and Alsace.

ORIGIN AND DESCRIPTION OF SPECIMENS.

A.

Specimens from Trinidad.

1. Forest Clay from Forest Reserve Fields, Fyzabad. Well 313, Bernstein Section. Core sample from 1170 ft.
2. Forest Clay from Well 313B, Trinidad Central Oilfields, Fyzabad.

* Paper received January 27, 1929.

[1] Taylor, E.McK. : "The Bearing of Base Exchange on the Genesis of Petroleum." J. Inst. Petr. Techn., 1928, **14**, 825-840.

3. Forest Clay overlying uppermost producing horizon. Apex (Trinidad) Oilfields, Fyzabad.
4. Silty Clay overlying Lot 1 producing sands, Apex (Trinidad) Oilfields, Fyzabad.
5. Guapo Field, depth 1485 ft., Trinidad Central Oilfields.

In connection with the above specimens, Beeby Thompson[2] remarks: "Most of the formations of Trinidad represent part of the great deltaic deposits of the Orinoco Delta." This indicates that the clay will have undergone base exchange as the normal clay type present in a deltaic deposit is sodium clay. The Forest Clay is of Middle Miocene age. The dominant foraminifera present is Cyclammina, indicating the marine origin of the deposit from which base exchange can be directly inferred. There is no record, however, of later freshwater conditions.

B.

SPECIMENS FROM MEXICO.

Producing Horizon: Yucatecal Sandstone (Lower Miocene).

6. Shale 80 feet above top of producing horizon.
7. " 70 " " " "
8. " 60 " " " "
9. " 50 " " " "
10. " 40 " " " "
11. " 30 " " " "
12. " 20 " " " "
13. " 10 " " " "
14. " 110 feet below " " "
15. } Taken from La Laja formation (Oligocene), about 800 feet below the
16. } top of the producing horizon.
17. }

C.

SPECIMENS FROM PECHELBRONN, ALSACE.

Niveau Principal.—II. Etage.

18. 0.30 metres above oil-bearing sand.
19. 0·60 " " " "
20. 0·95 " " " "
21. 1·10 " " " "
22. 1.58 " " " "
23. 3·00 " " " " (Specimen red probably due to weathering.)

Discussing the oil-bearing strata of Alsace, Beeby Thompson[3] states that a depression of the Rhine Valley "caused this area to be invaded by the sea in Tertiary times, while apparently minor movements caused an *alternation of salt and freshwater conditions.*" This statement is interesting as it is one of the few records of an alternation of the salt and freshwater conditions postulated for the

[2] Beeby Thompson, A.: "Oil Field Exploration and Development." Vol. I, p. 389.
[3] Beeby Thompson, A.: Loc. cit., p. 451.

development of alkalinity in the shales overlying petroliferous sands. The results of the examination of the shales from this area show that alkalinity was produced in the shales.

The oil-bearing strata of Alsace are of Oligocene age. The specimens of the shales examined are greenish-grey in colour and are rich in calcium carbonate.

Methods of Examination.

The determination of the pH value was made as described in the previous paper[4]. Owing to the presence of calcium carbonate in some of the specimens, a modification was introduced in the method of determination of the replaceable bases. The determination of replaceable sodium was made as previously described. Owing to the high solubility of calcium carbonate in ammonium chloride solution, the replaceable calcium was determined by base exchange with a normal solution of sodium chloride, as described by Hissink.[5] The results of these determinations are shown in Table I.

TABLE I.

pH Values and Replaceable Bases (milligram equivalent) in Shales overlying oil-bearing Sands in Trinidad, Mexico and Alsace.

Spec. No.	pH Value.	Replaceable Bases. (M.E. per 100 grs. shale.)	
		Ca.	Na.
(1)	9·2	1·7	29·1
(2)	8·8	2·3	31·4
(3)	9·4	5·1	29·6
(4)	9·0	0·7	24·5
(5)	9·0	(Replaceable bases not determined as specimen contained oil which prevented wetting with ammonium chloride solution.)	
(6)	8·8	4·0	63·5
(7)	9·0	4·5	40·8
(8)	8·6	3·2	47·5
(9)	8·6	6·5	40·0
(10)	8·8	2·4	33·5
(11)	8·8	3·4	47·2
(12)	8·6	2·5	59·7
(13)	8·8	5·5	43·4
(14)	8·6	4·7	48·6
(15)	9·8	2·3	40·7
(16	10·5	1·8	48·1
(17)	9·6	3·3	40·4
(18)	9·2	1·6	29·2
(19)	9·4	1·5	22·7
(20)	9·2	1·9	21·6
(21)	9·0	1·2	26·2
(22)	9·4	2·1	16·7
(23)	9·0	1·7	16·2

[4] Taylor, E. McK.: Loc. cit., p. 831.

[5] Hissink, D. J.: "Beitrag zur Kenntnis der Adsorptsionsvorgänge im Boden." Internat. Mitt. Bodenkunde, Vol. XII, p. 81, 1922

Discussion of Results.

From Table I. it will be seen that all the specimens are alkaline, the pH values indicating that the dominant clay type present is sodium clay. The results of the determinations of the replaceable bases show that the amount of replaceable sodium present is considerably greater than the amount of replaceable calcium, confirming the deduction made from the pH values that sodium clay is the dominant clay type present. The results show, therefore, that the shales examined have first undergone base exchange with solutions of sodium chloride and that the sodium clay thus formed has afterwards been hydrolysed in fresh water.

The shales overlying oil-bearing sands in Trinidad, Mexico and Alsace, therefore, agree with those of Rumania[6] and Venezuela in having undergone the processes of base exchange and hydrolysis. The results recorded in this paper thus lend support to the suggestion that the shales overlying oil-bearing strata are characterised by the presence of sodium clay in the process of hydrolysis and to the theory put forward in the previous paper as to the possible relation between base exchange and the genesis of petroleum.

I wish to express my thanks to the following Companies and gentlemen for their assistance in obtaining the specimens for examination :—

For the specimens from Trinidad : Messrs. Trinidad Central Oilfields, Ltd.

For the specimens from Mexico : Mr. J. McConnell Sanders, F.I.C.
For the specimens from Alsace : Mr. A. Beeby Thompson, and Messrs Société Anonyme d'Exploitations Minières, Pechelbronn.

[6] Taylor, E. McK. : Loc. cit., p. 832.

Apparatus for Fractional Distillation Under Vacuum.*

By Arthur A. Ashworth, M.A., A.M.Inst.C.E. (Member).

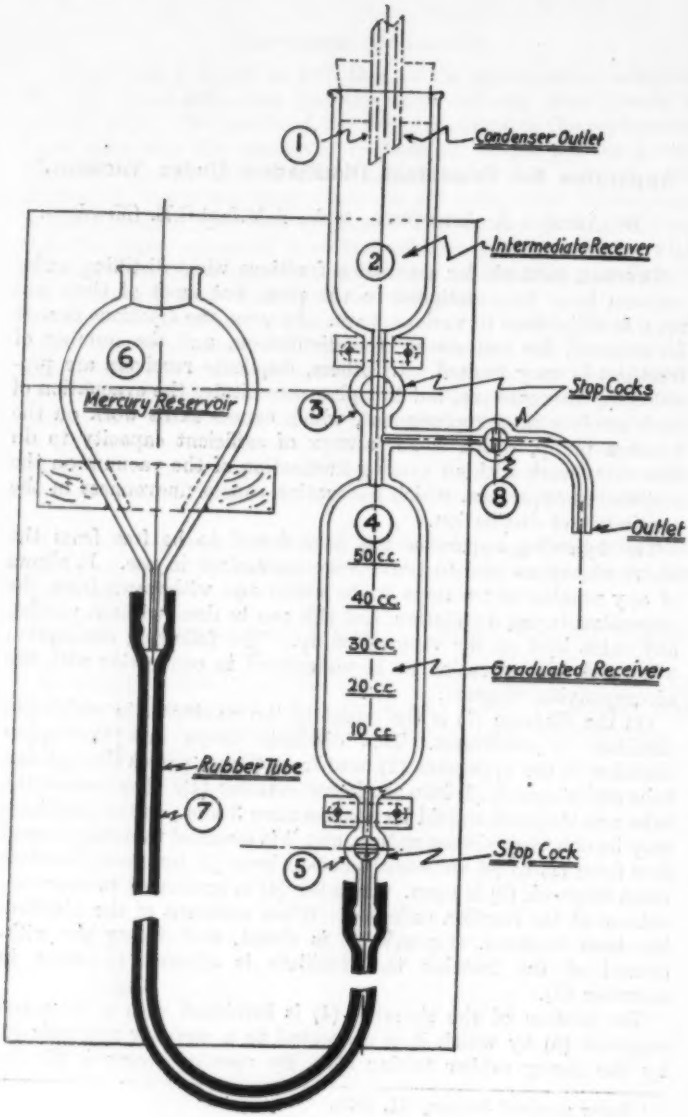
Several methods for separating fractions when distilling under vacuum have been designed in the past, but most of them are open to objections in various ways. In some the fractions cannot be removed for test during the distillation, and the number of fractions is very limited. In others, duplicate receivers are provided for alternate use, but this plan necessitates the evacuation of each receiver after replacement, which causes extra work on the vacuum pump, which is not always of sufficient capacity to do this extra work without causing fluctuation of the vacuum on the distillation apparatus, which fluctuation causes unevenness in the continuity of distillation.

The following apparatus has been found to be free from the above objections and to prove very convenient in use. It allows of any number of fractions to be taken and withdrawn from the apparatus during distillation, and this can be done without putting any extra load on the vacuum pump. The following description will enable the operation to be understood in connection with the accompanying diagram.

On the diagram (1) is the outlet of the condenser in which the distillate is condensed. This distillate drops into the upper chamber of the apparatus (2), and from thence passes through the tube and stopcock (3) into the lower chamber (4). The bore of the tube and stopcock should be not less than 3 mm., as the distillates may be of a very viscous nature, and it is essential that they should flow from (2) to (4) sufficiently fast to keep (2) free from distillate when stopcock (3) is open. Chamber (4) is graduated to show the volume of the fraction collected. When sufficient of the distillate has been received, stopcock (3) is closed, and during the withdrawal of the fraction the distillate is allowed to collect in chamber (2).

The bottom of the chamber (4) is furnished with a tube and stopcock (5) by which it is connected to a mercury reservoir (6) by the heavy rubber tubing (7). By opening stopcock (5) the

* Paper received January 11, 1929.


1
Condenser Outlet
2
Intermediate Receiver
6
Mercury Reservoir
3
Stop Cocks
8
Outlet
4
50 cc.
40 cc.
30 cc.
20 cc.
10 cc.
Graduated Receiver
Rubber Tube
7
5
Stop Cock

mercury displaces the distillate in chamber (4) and forces it through the delivery tube and stopcock (8) into the usual graduated cylinder. When the mercury has risen to the level of the delivery tube (8), stopcock (5) is closed and the mercury in chamber (4) is lowered below stopcock (5) which is then closed. Chamber (4) is then under full vacuum and, on opening stopcock (3) the distillate which has meanwhile collected in chamber (2) flows into chamber (4) to form part of the next fraction.

The writer has found it convenient when distilling lubricating oils to use a 1,500-c.c. flask and charge it with 1,000 grams of stock. Fractions of 50 c.c. are taken, and this amount allows of the weight of each fraction and the specific gravity to be taken during the course of the distillation. A 50-c.c. fraction is also sufficient to allow of the viscosity being observed by means of a B.E.S.A. pipette viscometer and the Open Flash Point by means of the Marcusson cup after the distillation is completed.

Methods of Refining Sulphurous Oils.

By C. J. Wright, B.A. (Cantab.) (Associate Member).

INTRODUCTION.

For a long time it has been felt that a large gap has existed between our detailed knowledge of the refining of crude distillates with especial reference to the removal of sulphur compounds, as acquired by small scale research work and the large scale application of refining processes.

Plant problems naturally arise which are unforeseen on a small scale, and an endeavour has been made in this paper to correlate, in order of sequence, troubles that have been experienced and overcome with various processes, with particular reference to the hypochlorite process.

Sulphur compounds occur in practically all crude oils, although to a widely varying degree, being as high as 4·7 per cent. in certain Wyoming crudes and as low as 0·06 per cent. in several Oklahama crudes.

Persian crude oils are intermediate with about 1·0 per cent. when free from hydrogen sulphide, while under similar conditions other Persian crude oils contain about 0·62 per cent. sulphur.

Many American crude oils are free from hydrogen sulphide, the latter compound being formed by chemical change only during distillation.

Certain Persian oils, on the other hand, contain very large amounts of this impurity and further quantities are formed during distillation. Other Persian oils in contrast contain very little hydrogen sulphide, and only a trace is found during distillation.

Thus it will be appreciated that every different type of crude oil must be investigated to judge which method of refining will be the most economical.

The types of sulphur compounds vary from crude to crude, and refining agents that will remove one type of compound may have little or no effect on another type.

To a certain extent, however, all refining schemes have a common link, in that refining a crude distillate virtually means improving the odour to such a degree that it is considered sweet to the sense of smell.

A refined oil of very high sulphur content eventually must have a greater deleterious action as regards engine and exhaust corrosion, but providing the sulphur is within reasonable limits the motoring public requires a spirit with a good odour.

Apart from sulphuretted hydrogen, which is highly corrosive and must be removed, the only other type of compound usually found in crude distillates that must be eliminated or changed to sweeter smelling compounds is the mercaptan. Various refining agents will bring about this change—with or without affecting other types of sulphur compounds.

The common chemicals employed commercially for removing sulphur compounds from oils are as follows:—

(1) Caustic soda and lime.
(2) Calcium or sodium hypochlorite.
(3) Litharge or sodium plumbite.
(4) Sulphuric acid.
(5) Liquid sulphur dioxide.
(6) Bauxite or fuller's earth, etc.

Although these chemicals are all refining agents in the strict sense of the word, they act by virtue of different properties, while in several cases the chemical can be partially or completely recovered economically.

A brief account of the above agents is given at this stage in order that a complete picture of their various uses and limitations can be visualised.

1. Caustic Soda.

(*a*) *Removes hydrogen sulphide.*—For this purpose it can be used at any reasonable strength, say, from 0·1 up to 10 per cent. solution. It is equally efficient at all concentrations up to 90 per cent.

The sodium sulphide so formed can be partially recovered by the Koppers process, which consists essentially of aeration, causing hydrolysis of the sulphide, liberation of the sulphuretted hydrogen and regeneration of the soda. This recovery is comparatively cheap between limits, being of the order of 20 per cent. of the cost of fresh soda equivalent to the soda regenerated. Actually to recover the equivalent of 1 lb. of soda costs approximately one-third of a penny.

(*b*) *Removes mercaptan.*—These are acidic bodies akin to hydrogen sulphide but with heavier radicles in the molecule, whose removal is only partial, depending on the type of mercaptan dealt with. The solution of mercaptides in excess of soda can be partially recovered by boiling, when they become hydrolysed, regenerating the previously extracted mercaptans as volatile compounds. This regeneration is only partial, but again varies with the type of

mercaptan to be dealt with. In some cases, it is economical to recover this soda, for the recovery can be effected with practically 100 per cent. efficiency, but with certain Persian crudes, however, the recovery cannot be effected beyond about 90 per cent. efficiency. *Lime*, which was coupled with caustic soda as a refining agent, is as efficient as the latter chemical at equal dilutions. However, the solubility of lime being in the neighbourhood of 1 pound per 100 gallons, about 70 times the volume of liquor would be required to equal an equivalent quantity of soda in 10 per cent. solution. Handling charges are proportionately larger, and recovery is precluded on account of the large bulk of liquor to be treated. Soda or lime will not remove any other class of sulphur compounds present in crude distillates. The remaining primary types of compounds encountered are :—

I. Sulphides.
II. Disulphides.
III. Cyclic compounds containing a sulphur atom in the ring.
IV. Elementary sulphur.*

2. Hypochlorite (Sodium or Calcium).

This agent functions essentially by virtue of its oxidising properties and, once exhausted, could only be recovered electrolytically, which is an uneconomical proposition.

Hypochlorite has been used most extensively for many years, and the improvements brought about by a meticulous study of the chemistry of petroleum refining have made the use of this chemical one of the most economical methods of desulphurising crude oil distillates.

The word "desulphurising" has been particularly chosen here on account of a process that will be dealt with later—called the "Plumbite" process. This method of refining is probably cheaper in certain localities, but is used merely to render an oil "sweet" irrespective of the final sulphur content of the finished product.

Returning to hypochlorite, this should only be used after sulphuretted hydrogen has been removed by caustic soda or lime, otherwise undesirable elemental sulphur is formed by direct oxidation.

Hypochlorite removes :—

(*a*) *Mercaptans.*—These compounds are partially converted to acidic bodies, which are removed by the alkali in the bleach solution and partially converted to innocuous sulphur compounds having

*To save confusion later, it should be mentioned here that whereas soda and sulphur do not react, sodium sulphide is a moderately good solvent forming soluble polysulphides.

a higher state of oxidation but which are oil soluble and therefore not removed. The degree to which this oxidation preponderates on the "removal" or "conversion" side depends on the mode of treatment and the "reactivity" of the hypochlorite.

(*b*) *Sulphides.*—These are oxidised completely to sulphones, water and oil soluble compounds, which are removed partly by the bleach liquor and then by water washing.

(*c*) *Disulphides.*—These are partially oxidised to acidic bodies and removed as such. The reaction is very slow but can be accelerated, if desired, by careful control of the alkalinity of the hypochlorite solution.

Other more common sulphur compounds not affected by hypochlorite are :—

I. Thiophenes.

II. Elemental sulphur.

3. Litharge or Sodium Plumbite.

This is one of the oldest of refining agents and is still very much used in the United States.

Until comparatively recent years its method of reaction was not very clearly understood, but it was definitely known that the oil was sweetened. The process must always be followed by redistillation, however, with a final small plumbite treatment of the distillate before the oil is a finished marketable product.

In the light of subsequent work it has been shown that, apart from hydrogen sulphide, the plumbite treatment chemically does not remove any sulphur compounds at all. Litharge and flowers of sulphur react with mercaptans. These compounds are converted to lead mercaptides, which react with the flowers of sulphur (a necessary addition) to form disulphides and lead sulphide, all the sulphur in the sulphide coming from the flowers of sulphur. Virtually no sulphur is removed, but a slight adsorption by lead sulphide of disulphides or other sulphides present usually takes place, causing a slight diminution in sulphur content.

After redistillation, however, a further reduction in sulphur in the distillate takes place with a corresponding increase in sulphur in the residue. This is due to the conversion of mercaptans into disulphides, being accompanied by a rise in boiling point from between 60° C. and 120° C.

If the residue requires desulphurising, the problem is only shelved and the plumbite treatment would not be worthy of much consideration.

The lead sulphide, which remains suspended in a solution of soda after treatment, can be recovered by two distinct methods :—

(*a*) *Air agitation method.*—The sludge is heated to 180° F. with closed steam and air blown. The plumbite is regenerated, but recovery is not good and the process is not highly efficient.

(*b*) *Recovery with acid.*—The lead sulphide precipitated is removed by filtration and treated with waste sulphuric acid obtained from acid sludge. The lead sulphate is separated, washed with water, and digested with caustic soda whereby the plumbite is regenerated. In this way 90 per cent. of the lead is recovered. No costs are available, but considering the cheapness of the spent acid these should be low. More recently experiments have come to notice which are a development of (*a*) above, whereby the recovery of lead sulphide is effected during treatment by air agitation.

It has been claimed by this practice that the same degree of refining can be achieved with one-tenth the theoretical quantity of litharge, but the writer has not been able to check these statements. It may be possible that the mercaptans themselves are directly oxidised by atmospheric oxygen, but in the absence of litharge, this reaction is slow and inappreciable even after several hours agitation.

The following type of sulphur bodies encountered in crude oil are unaffected by Plumbite.

I. Sulphides.
II. Disulphides.
III. Cyclic compounds containing sulphur in the ring.
IV. Elementary sulphur.*

4. Sulphuric Acid.

This is a refining agent extensively used in the oil industry and one which has an effect on quite a wide range of sulphur compounds. One of the chief objections to its use, however, is the trouble in disposing of acid tar and the avoidance of river contamination.

The effect of sulphuric acid on sulphur compounds varies in degree according to the strength of the acid. Two main strengths are used: C.O.V., about 96 per cent. acid, and F.O.V., which contains up to 20 per cent. of free sulphur trioxide, the latter acid being more vigorous in its action. Mercaptans, disulphides, sulphides and ring compounds such as thiophanes are all removed to varying degrees according to the strength of acid.

* This, of course, is essential in the plumbite process, and if present would be removed in the course of the conversion of mercaptan to disulphides. There is no direct action, however, between elementary sulphur and litharge.

Sulphuretted hydrogen[1] is converted into free sulphur, so that this should not be present when acid washing.

Free sulphur[1] *is unaffected.*—In the above reactions sulphuric acid appears to act partially by virtue of its oxidising properties and partially on account of its solvent properties.[2]

Mercaptans appear to be partially oxidised to disulphides, and these in turn to sulphonic acids.

Sulphones and sulphides have been isolated from acid tar,[3] which points to both an oxidising and a solvent action.

Thiophenes are oxidised.[1]

5. Liquid Sulphur Dioxide.

This is the first example so far of a refining agent that acts purely as a solvent, and can be recovered completely apart from very slight handling losses at each stage.

Systematic work does not seem to have been carried out on the types of sulphur compounds dissolved by liquid SO_2, but it is obvious that a process that has merely a solvent action can only effect a partition between the oil and the liquid layer, and can never remove completely any one type of sulphur compound without an infinite number of extractions.

Washing with liquid sulphur dioxide is a comparatively expensive treatment, but apart from this it would never be used on motor spirit on account of the valuable aromatic compounds that would be extracted at the same time.

Furthermore, apart from these considerations, the objectionable mercaptans in unrefined motor spirit would only be partially removed, and resort to an additional refining agent would have to be made. Liquid sulphur dioxide is used chiefly for refining kerosine, and the value of the aromatic compounds recovered makes the process quite economical.

Without being able to quote any figures, it may be said that liquid SO_2 removes the following sulphur compounds (the degree depending on the number of extractions):—

Mercaptans,
Disulphides and
Cyclic sulphur compounds.

Elemental sulphur is apparently unaffected.

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[1]Wood Sheely and Trusty, *Ind. Eng. Chem.*, 1926, **18**, 169.
[2]Dunstan. Cantor Lectures, *Roy. Soc. Arts*, 1928, p. 57.
[3]Gurwitsch. "Scientific Principles of Petroleum Refining."

6. Bauxite—Fuller's Earth, etc.

These are refining agents which come under yet a different category and act by preferentially adsorbing sulphur compounds on their surface or in the pores of their structure.

Once adsorbed, the sulphur compounds can only be completely removed by raising the temperature to 500° or 600° C. (in the case of bauxite) and oxidising with air. The degree of regeneration of the bauxite is practically 100 per cent., and the same bauxite re-roasted can be used effectively for several cycles. Continual handling eventually causes disintegration, and so the bauxite slowly becomes powdered and fresh make-up supplies have to be used from time to time. At one time it was considered that the process was purely a physical phenomenon, but there is certain evidence which goes to show that with some sulphur compounds chemical changes are induced during filtration. For example, it is thought that mercaptans undergo a catalytic-surface oxidation by means of the dissolved oxygen in the oil and give rise to the formation of disulphides. Mercaptans may or may not be removed, but the transformation to the higher state of oxidation and removal would appear to proceed more readily. Sulphides and ring sulphur compounds are removed, but no comparative figures can be quoted.

The treatment is necessarily expensive, and involves high loss figures, and as a means for refining motor spirit would be prohibitive. Such minerals are very useful refining agents for kerosine on account of their decolourising as well as desulphurising powers, and it is for the former reason mainly that such filtering media are used. The desulphurising effect is very convenient, but without the decolourising effect such refining agents most probably would never be used for the refining of oil.

The cost for desulphurising alone would be out of all proportion to other methods.

Plant Application of Refining Methods.

Under this heading refining methods will be reviewed from the point of view of the advancement made over a period of years both in plant design and economies in treatment. This latter study has been made possible by a better understanding of the sulphur compounds contained in crude distillates, a knowledge which has been gained as a result of intensive research work.

Plant Washing Equipment.

Originally all washing was performed on the batch principle. Each washer was fitted with a centrifugal circulating pump delivering through sprays, and all chemical feed lines delivered overhead

into the washer. The series of chemical treatments necessary were performed in rotation in the same washer, after the chemical from the previous treatment had been settled and run off.

No motor spirit was taken straight from the crude oil by primary distillation, but one-third of the crude was distilled off as "Once Run Distillate," which contained both the benzine and the kerosine. This contained much sulphuretted hydrogen and was given a preliminary soda wash in one or more stages. The washed oil was then redistilled to give an unrefined motor spirit distillate and a kerosine residue.

The spirit was next batch washed with hypochlorite solution to a degree which resulted in a final sulphur content of *circa* 0·015 per cent.

Towards the end of 1924 the first effort was made to introduce continuous washing. A group of batch washers were linked up, using the agitating pumps both for washing and transferring the washed spirit forward through the plant.

This plant worked well. It was found unnecessary to synchronise all the pumps, because if one washer started to "bank up" with spirit, the pump it was feeding, being a centrifugal one, would automatically pump at a faster rate owing to the increased head, and thus tend to clear the excess of oil.

The feature of this plant is the possibility of using a large bulk of washing liquor at each stage without using a larger consumption of chemical, which results in much more efficient treatment.

The ideal mixture to have in the pump is "50/50," and one such wash at each washing pump suffices to give the desired result, although the actual time of contract between chemical and spirit is only a matter of seconds.

The continuous type of washing unit adopted consisted of a number of washing stages, viz.:—

Hypochlorite treatment	4 stages
Soda treatment	5 stages
Water washing	1 stage

Subsequently to this phase a different type of continuous washing unit has been evolved and has proved a success. This consists of a string of mechanically agitated washers and separators. Approximately the same number of stages are required as above —namely 10, but the pumping charges are reduced to about 60 per cent.

The plant also has a very much lower initial cost and lower labour charges.

Saving in hypochlorite is not so great, but with the mechanically agitated plant one can use lime water instead of soda solution, and so effect appreciable economies.

A third type of washery, that has recently been adopted for treating smaller quantities of oil, is the orifice washing unit. These units were originally installed for soda washing only, but have been adopted for bleach washing and more recently a continuous plant has been designed to fully refine light gasoline, including initial soda washing, bleach washing and final soda washing.

Soda Washing Practice.

Soda is used as a preliminary refining agent on all distillates primarily to remove sulphuretted hydrogen. In addition to this, soda removes mercaptans to a varying degree, depending on the percentage wash given and the strength of soda used. At various times during the last few years this soda wash has been given in one or two washes, either discontinuously or continuously. At one period the spent soda was "recovered" by boiling in a pot still, taking off on the average from 15 to 25 per cent. of the liquor as steam. This had the effect of removing with it a certain percentage of mercaptans from the soda.

Counter current washing is recognised to be more efficient than batch washing, and the latest soda washers installed effect the removal of mercaptans in two counter current washes and then hydrogen sulphide from the incoming spirit at a third stage.

Sulphuretted hydrogen, being a stronger acid than mercaptan compounds, tends to turn the latter out of solution. Consequently when using soda containing mercaptans for removing hydrogen sulphide, care must be taken that such does not happen, otherwise the process would tend to fail.

The limits to which one can use fresh soda and mercaptan soda have been carefully worked out both with unrecovered soda, so-called "recovered" soda and so-called "half recovered" soda. See Graph 1.

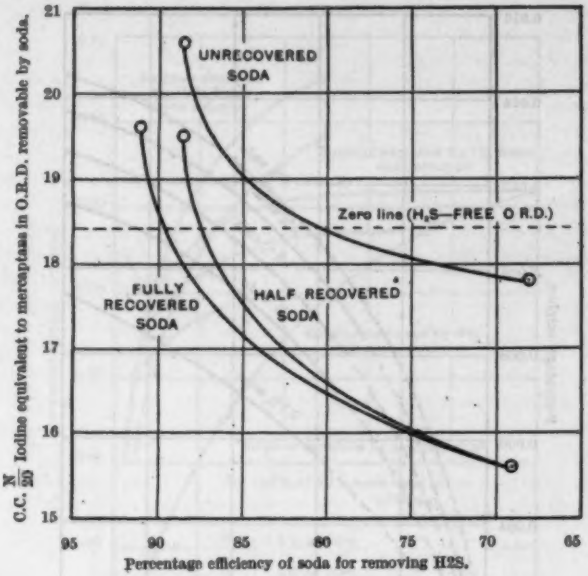
This recovery and "half recovery" was accomplished in the pot still plant previously mentioned. The fully recovered had 25 per cent. distilled off, and the half recovered 12½ per cent., during the process of recovery.

This process has been shown to be uneconomical, because without recovery the soda can be used up to 80 per cent. efficiency without throwing out mercaptans, and only up to 87½ per cent. efficiency if "fully recovered"; this difference of 7½ per cent. does not warrant the expense of recovery.

The economical situation is as follows:—

For the purposes of discussion, straight-run benzine only is considered.

The straight-run benzine from the crude benches contains large quantities of sulphuretted hydrogen depending on the pipe still worm end temperature. It materially assists refining costs, if the temperature is maintained as high as 90° or 100° F., when



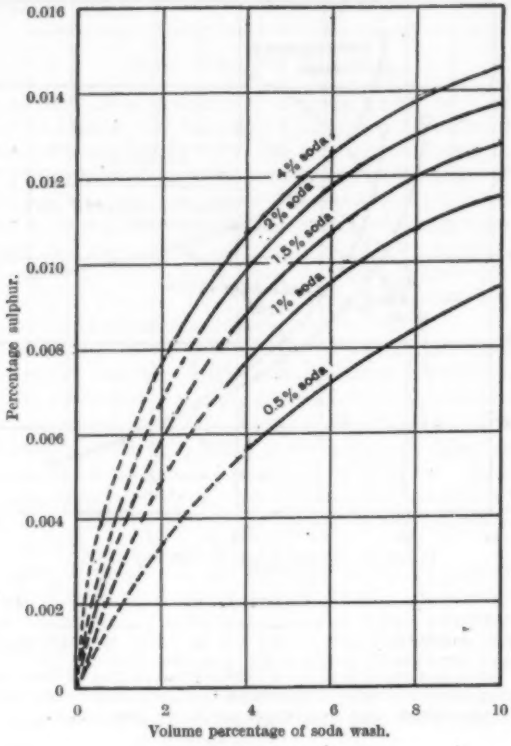
GRAPH 1.

COMPARATIVE MERCAPTAN CONTENT OF CRUDE O.R.D. WASHED WITH UNRECOVERED AND RECOVERED SODAS WITH VARYING DEGREES OF SODA EFFICIENCIES. IN EVERY CASE BEYOND A CERTAIN POINT THE CURVES GO ABOVE THE ZERO LINE, SHOWING THAT MERCAPTANS ARE LIBERATED BY THE HYDROGEN SULPHIDE AND PARTITION BACK TO THE O.R.D.

the soda consumption for the complete removal of hydrogen sulphide is about 3 lb. of soda per ton of straight-run benzine. If the temperature be allowed to fall between 70° F. and 80° F., the soda consumption is increased by 50 per cent. at least. Such a quantity of soda is the bare minimum necessary. Regarding the removal of mercaptans, a certain reduction can be effected by soda before the bleach treatment. Actually, if 4½ lb. of soda per ton of straight-run benzine is necessary for hydrogen sulphide

removal, then this quantity at a suitable dilution is used counter currently to remove mercaptans before the sulphuretted hydrogen.

The mercaptan sulphur removed by varying washes of soda is shown by Graph 2.



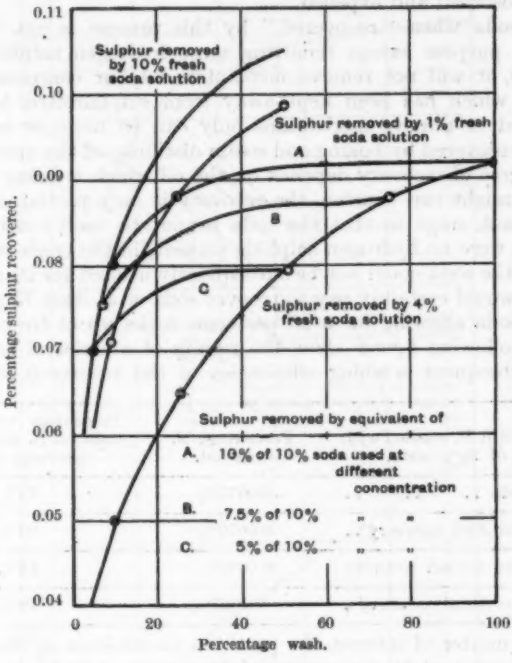
GRAPH 2.

SULPHUR REMOVED FROM S.R.B. BY VARIED WASHES OF VARYING STRENGTH SODA.

A consideration of the economies of the use of soda and hypochlorite to produce a benzine of given specification irrespective of the hydrogen sulphide content, shows that the most economical usage is between 5 per cent. of 1 per cent. and 3 per cent. of 1½ per cent., or better still 10 per cent. of ½ per cent. soda.

There is a minimum point here, and this consumption would be adhered to if it were not for the fact that excess soda beyond this is required for hydrogen sulphide removal.

Actually, 5 per cent. of ½ per cent. solution followed by bleach treatment of 2·2 gms. per litre is most economical.



GRAPH 3.

SULPHUR REMOVED BY VARYING WASHES OF VARYING STRENGTH FRESH AND RECOVERED SODA SOLUTIONS.

Here, again, one never finds a sufficiently small quantity of hydrogen sulphide present, to be able to use such a small soda wash, and the question resolves itself into using the minimum quantity of soda for mercaptan removal that, when passed on for hydrogen sulphide removal, it will be sufficient to remove all the hydrogen sulphide from the incoming spirit.

Reviewing the possibility of recovering spent soda, we have two factors to remember, namely, sulphide and mercaptide content.

A working process for partially recovering sodium hydrosulphide exists in the Kopper's process, which consists of aeration of the hydrosulphide whereby hydrogen sulphide is liberated and an equivalent amount of sulphide formed. About a 5 per cent. recovery takes place economically, and working between these limits with a large bulk of liquor, hydrogen sulphide can be alternatively absorbed and expelled.

The soda when "recovered" by this process is not valuable for any purpose except removing more hydrogen sulphide; for instance, it will not remove mercaptan sulphur compounds.

Soda which has been kept away from sulphuretted hydrogen and used to remove mercaptans only can be more or less completely recovered by boiling and steam distilling off the mercaptans. The degree of recovery depends on the oil which is being washed. With straight run benzine, the recovery is only partial, and falls off at each stage so that the soda cannot be used continuously. If there were no hydrogen sulphide present, in the crude distillate, so that the soda could not be subsequently utilised for its removal, then it would certainly pay to recover soda or at least 75 per cent. of the soda allowing for a 25 per cent. make up of fresh soda.

The following figures show the results of a series of recoveries with subsequent washing efficiencies of the recovered soda.

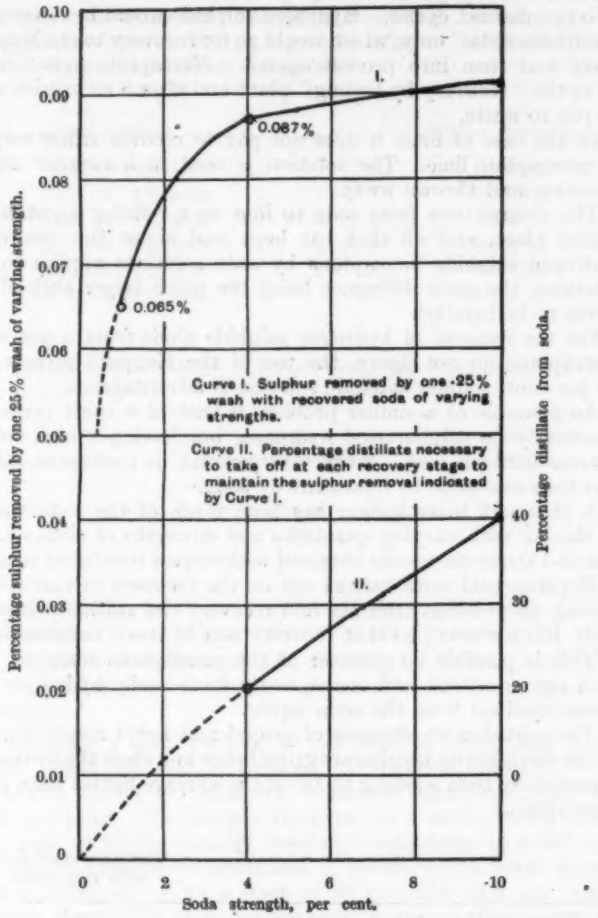
H_2S free S.R.B. washed with 4% of 2½% soda.	Percentage S. removed.	Percentage recovery of soda on S. removed by previous wash.
Fresh soda	0·0075%	70%
Soda after first recovery ..	0·0070%	93%
Soda after second recovery	0·0062%	84%
Soda after third recovery .	0·0057%	76%

As a matter of interest the partition co-efficients of the S. compounds removed by 5 per cent. of 2 per cent. soda wash are compared with the partition co-efficients of propyl and butyl mercaptans with 2 per cent. soda.

	Partition coefficient with 2% soda.
Mercaptans removed by 5% of 2% Soda wash .	4·3
Propyl Mercaptan	6·6
Butyl Mercaptan	1·6

Hence the average mercaptan sulphur compound removed lies between propyl and butyl mercaptan.

It will be seen that a gradual falling off in efficiency takes place, but even after 3 recoveries a 76 per cent. efficiency is obtained when compared with the initial wash with fresh soda.



GRAPH 4.

Actually the economical limit is about 8 times, after which it pays to start afresh.

Virtually, then, we have two processes for recovering soda, one for partial recovery of sulphide and the other for recovery of "mercaptide soda." If soda were the only alkali that could be used, it would pay them to segregate the soda used in the refinery into two distinct cycles. Hydrogen sulphide would be removed by "sulphide soda" only, which would go for recovery to the Kopper's plant and then into process again. "Mercaptide soda" would go to the "recovery by boiling" plant and after 8 recoveries would be run to waste.

In the case of lime, it does not pay to recover either sulphide or mercaptan lime. The solution is used in a counter current direction and thrown away.

The change over from soda to lime as a refining agent is now taking place, and all that has been said about the removal of hydrogen sulphide mercaptans by soda solutions applies to lime solutions, the main difference being the much larger bulk of lime water to be handled.

For the removal of hydrogen sulphide alone from a gas where mercaptans do not figure, the use of the Kopper's process with 10 per cent. sodium sulphide solution is advantageous.

An example of a similar problem is that of a spirit containing practically no sulphuretted hydrogen, but having a high sulphur content 0·22 per cent., of this 0·17 per cent. is mercaptan sulphur and thus amenable to treatment by soda.

A thorough investigation has been made of the soda washing of this oil with varying quantities and strengths of soda solution. Graph 4 shows the results obtained with respect to sulphur removed.

Experimental work carried out on the recovery of this soda by boiling showed that after the first recovery the efficiency is practically 100 per cent., so that recovery can be made continuously.

This is possible on account of the mercaptans removed being of a lighter nature and consequently more easily hydrolysed and steam distilled from the soda liquor.

The partition co-efficients of propyl and butyl mercaptans and of the straight run benzine are given below and show the mercaptans removed by soda washing to be on the average lighter than propyl mercaptan.

	Partition coefficient with 10% soda.
Mercaptans in S.R.B.	25·0
Propyl Mercaptan	17·8
Butyl Mercaptan	4·1

By reference to page 226, it will be seen that soda from mercaptan washes from some Persian spirit contained heavier mercaptans, which accounts for the fact that it could not be recovered completely like the above soda.

The increased efficiency of mercaptan removal, by using equivalent quantities of soda but at a greater dilution, is shown by the following figures taken from Graph 3.

	Soda washed.	Sulphur removed.
A.	10% of 10% soda	0·080 %
	25% of 4% soda	0·0875%
	100% of 1% soda	0·092 %
B.	5 % of 10% soda	0·070 %
	12½% of 4% soda	0·0745%
	50 % of 1% soda	0·079 %

The partition co-efficients of 10 per cent. and 1 per cent. soda are given below :—

Strength soda.	Partition Coefficient.	Part. Coefficient strength soda (percentage).
10%	25·0	2·5
1%	5·1	5·1

This shows the partition co-efficient percentage soda to be twice as high for 1 per cent. soda as for 10 per cent. soda.

Experimental investigation into recovery of varying strength sodas by boiling showed clearly that weaker soda is more easily recovered.

For example, a soda wash of 25 per cent. of 10 per cent. soda removes 0·0965 per cent. of sulphur. To recover this soda, it is necessary to add 40 per cent. by volume of water, and distil off this 40 per cent. The sulphur removed by a similar wash with 25 per cent. of 10 per cent. of recovered soda drops to 0·092 per cent., but with the same conditions of recovery this latter figure can be maintained. With a wash of 25 per cent. of 4 per cent. fresh soda, the sulphur removed is 0·0877 per cent. After recovery, which entails distilling off 20 per cent. only of the liquor (vide Graph 4), the same soda wash removes 0·0870 per cent., and this figure can be maintained indefinitely.

The experimental results are tabulated below :—

(*a*) 25% of 10% soda wash.

Stage.	Percentage soda wash.	Sulphur removed from oil per cent.	Sulphur in Soda before recovery. gms./25 c.cs.	Sulphur in soda after recovery. gms./25 c.cs.	Percentage recovery of soda on sulphur. removal.
1	25% of 10% fresh soda	0·0965	0·0965	0·0149	84·5
2	25% of 10% recovered soda	0·092	0·1069	0·0155	99·2
3	25% of 10% recovered soda	0·089	0·1045	0·0149	100·6
4	25% of 10% recovered soda	0·91	0·1059	0·0149	100

(*b*) 25% of 4% soda wash.

Stage.	Percentage soda wash.	Sulphur removed from oil per cent.	Sulphur in soda before recovery. gms./25 c.cs.	Sulphur in soda after recovery. gms./25 c.cs.	Percentage recovery of soda on sulphur. removal.
1	25% of 4% fresh soda	0·0877	0·0877	0·0202	77·0
2	25% of 4% recovered soda	0·0867	0·1069	0·0138	107·0
3	25% of 4% recovered soda	0·0871	0·1009	0·0150	98·8
4	25% of 4% recovered soda	0·0865	0·1015	0·0148	101·5

The weaker the soda used, the greater the efficiency of sulphur removal, but larger volume washes mean greater cost to recover the soda and the economic balance must be carefully studied.

Before leaving the subject of soda it is worthy of note that, taken in conjunction with sulphuretted hydrogen or sodium sulphide formed thereby, an efficient agent for removing elemental sulphur is obtained.

The reaction is by no means slow, and a comparatively large reduction takes place in a short space of time even in an agitating pump where the soda meets the sulphurous spirit. An enhanced effect is produced if the mixture of spirit and soda be passed subsequently through a string of orifice mixers.

Similar results are obtained in mechanically agitated washers where the time of contact is even greater.

As an example of the reduction effected, the following test results are quoted: soda and crude spirit were taken into the pump suction together and delivered through a series of five orifice mixers. In several cases sulphide was circulated back to the pump suction, meeting fresh soda and sulphurous oil, thereby increasing the percentage wash. This showed a distinct improvement.

Experiments with S.R.B.

Percentage soda/oil ratio.	Fresh soda strength. Per cent.	Percentage conversion to sulphide.	Elemental sulphur in crude spirit. Per cent.	Elemental Sulphur in spirit ex. charging pump. Per cent.	Elemental sulphur in spirit after one string of 5 orifice mixers. Per cent.
4% by volume (no soda recycled)	2·56	69	0·009	0·002	0·0009
15% by volume 11% by volume recycled	2·56	69	0·009	0·0018	0·0006
10% by volume 3% by volume recycled	2·00	70	0·0028	—	0·0010
10% by volume (no soda recycled)	1·10	75	0·0018	0·0006	0·0004
10% by volume 6% of soda recycled	2·6	80	0·0006	—	0·0003

The sulphur is taken up by the sulphide, forming sodium polysulphides.

The removal of elemental sulphur is always desirable, and considerable attention has been paid to this method of achieving the result on a large plant scale. A figure of under 0·0005 per cent. is maintained, a lower figure being an unnecessarily high degree of refinement.

Refining by Hypochlorite.

Attempts were made by various investigators to use hypochlorite for refining sulphurous oils as long ago as 1894, but for many years, however, the process was not applied on a commercial scale. This was mainly due to the fact that the key to its successful application lies in a careful control of the alkalinity, particularly with sodium hypochlorite which was largely used in the early experimental days. Secondly, the process was not too economical, but the advent of war, which brought a demand for liquid chlorine on a huge scale, necessitated large and efficient plant for manufacturing purposes which has resulted in comparatively cheap chlorine.

Methods of transportation also developed along safe and cheaper lines. This gave a fillip to the hypochlorite process, which was reinvestigated by A. E. Dunstan and F. B. Thole, and finally successfully applied on a large plant scale.

References to earlier work on this subject are as follows :—

Brin and Brin.—E.P. 10,968 (1896).—Oils treated with gaseous ozone and chlorine.

Frasch.—U.S.P. 525,811 (1894).—Oils agitated by suspension of chloride of lime, followed by sodium plumbite claimed to dechlorinate.

Gray.—E.P. 5132 (1889).—Agitates oils with solution of chlorinated caustic soda or potash.

Armstrong.—U.S.P. 837,655 (1906).—Refines petroleum distillates by shaking with a clear solution of chloride of lime, to which alkaline carbonate is subsequently added.

Frasch.—U.S.P. 622,799 (1899).—Oils refined by free chlorine, and subsequently chlorinated products removed by basic metallic salts.

Colin and Amend.—U.S.P. 123,368 (1903).—Oils de-sulphurised by alkaline solution of hypochlorites to which catalysts are added in the form of salts of metals such as, manganese, cobalt, nickel, copper, iron, etc. All those metals are polyvalent, i.e., form more than one class of oxides and salts. On addition to alkaline hypochlorite the hydroxides of the metals are formed which are claimed to have a catalytic effect. With an oxidising medium, the highest oxide of these metals is formed which was claimed to oxidise the sulphur compounds, themselves becoming reduced, and in turn reoxidised by the hypochlorite. Subsequently to this work as mentioned above, the process was actually developed by Dunstan & Thole (see *J. Inst. Petr. Techn.*, 1924, **10**, 201).

Brin and Brin must have produced a refined oil—negative to the doctor test, but very highly chlorinated.

Frasch (1894) was very near the truth, but his claims to dechlorinating with plumbite are erroneous.

Gray.—Here the effect of controlled alkalinity was not fully understood, so that large scale application could not have been successful.

Armstrong.—This investigator was very much nearer the solution to the application of calcium hypochlorite, but did not succeed in dechlorinating the finished spirit.

Frasch (1897).—This patent was a retrograde step from the patent of 1894.

The claim to dechlorinate by means of metallic basic salts could not have been very successful.

Colin and Amend.—These investigators, in their endeavour to speed up the process by catalysing agents, unconsciously stumbled on one solution to the successful application of the process, but failed to dechlorinate the final product.

The theory of catalysis in the patent is erroneous, and the metallic salts added merely remove a certain amount of alkalinity and render the hypochlorite solution more reactive and so a more efficient desulphuriser.

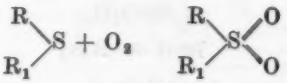
Moreover, the precipitation of metallic hydroxides as achieved by this patent is a very unsatisfactory factor in a large scale plant owing to highly stable emulsions formed during the washing process, which creates great difficulty in separating the aqueous and spirit layers after treatment.

Action of hypochlorite on sulphur compounds.—This subject has been fully dealt with in the literature,* and it is not intended to dwell upon the question to any length. The reference below to the article by Birch and Norris gives a particularly good account of the reactions with various sulphur compounds with sodium hypochlorite having various degrees of stability, and shows very clearly the effect of a varying alkalinity on the reactivity of the refining agent.

Sulphides, disulphides and mercaptans are all investigated.

A few extracts are given, however, to cover points of general interest.

Effect of hypochlorite on sulphides.—In this reaction the sulphide is converted quantitatively to a sulphone which oxidation requires four atoms of chlorine or two atoms of oxygen per atom of sulphur oxidised :—



These sulphones are water and oil soluble, but much more so in water, and thus mostly removed by the hypochlorite solution. A subsequent water wash removes practically all the remainder by partition.

The effect of alkalinity on the reaction time is shown by the following table. The times of agitation are not given as they are really meaningless, the washing effect being a function of the rate

*Dunstan. *J. Inst. Petr. Techn.*, 1924, **10**, 201.
Birch and Norris. *J.C.S.*, 1925, **127**, 1934.
Wood; Sheely and Trusty, *Ind. Eng. Chem.*, 1926, **18**, 169.

of agitation, but all experiments were carried out at a standard rate of shaking for the same length of time.

Free Alkali. Per cent.	Available chlorine 8·42% by weight. Diethyl sulphide. S = 0·736 per cent. Per cent. removed.	Din-propyl sulphide. S = 0·864 per cent. Per cent. removed.	Di-isobutyl sulphide. S = 0·912 per cent. Per cent. removed.
0·22	100	95·7	36·2
0·37	100	95·7	38·4
0·54	100	95·7	
0·91	100	94·2	Decreasing
1·48	100	89·6	to
2·87	100	71·1	6·6
4·14	100	50·3	
6·64	100	16·4	

These percentage alkali contents are exaggerated beyond all limits ever used on a large plant scale, but they serve to show the effect which applies over a wide range.

Effect of hypochlorite on mercaptans.—Here, again, the alkalinity plays a great part and the reaction goes by various paths, the mercaptan being converted either directly to a sulphonic acid (the highest stage of oxidation), which is soluble in the alkali of the hypochlorite forming a salt which as such is removed, or *via* the intermediary stage of disulphides, which themselves are partially converted to the higher stage of oxidation (sulphonic acids again). This transformation may be depicted as follows:—

$$\begin{array}{l} \nearrow RSO_3H \nwarrow \\ RSH \rightarrow R_2S_2 \\ \searrow H_2SO_4 \swarrow \end{array}$$

The intermediary stage of disulphides requires only one atom of chlorine for each atom of sulphur converted, but the product is an oil and remains in solution in the spirit—no sulphur being removed.

The oxidation to the sulphonic acid requires 6 atoms of chlorine, per atom of sulphur converted, but the sulphur is thereby definitely removed.

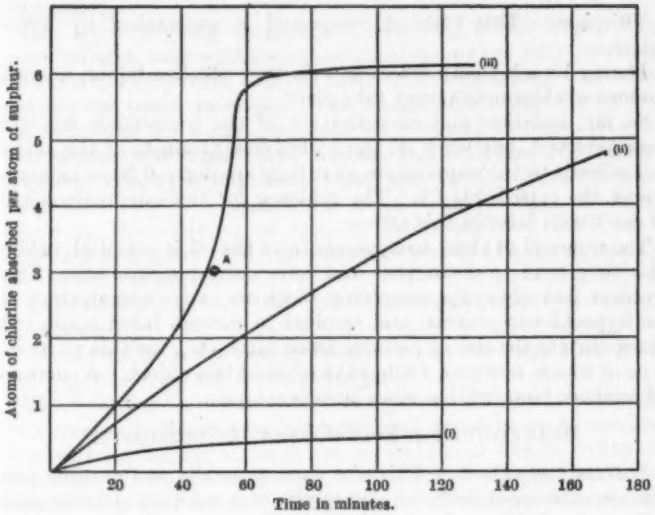
The following table shows the effect of increasing alkalinity on the oxidation of ethyl mercaptan—one of the most easily oxidised

compounds of this class. All rates and shaking were standard and the time was the same.

Sulphur content of unrefined oil—0·715 per cent.

Free alkali, per cent. ..	0·22	0·37	0·54	0·91	1·18	2·86	6·64
Per cent. S. in alkali treated oil.	Nil	Nil	0·03	0·11	0·12	0·14	0·19

Organic disulphides.—This class of compound is much more difficult to oxidise, and the alkalinity of the hypochlorite solution has a very marked effect on the rates of the reaction.



GRAPH 5.

During the oxidation, the sulphonic acid formed neutralises alkali present and increases the speed of reaction. Up to a point this is desirable, but the point of neutrality must be avoided, otherwise an acid bleach liquor causes excessive consumption and chlorination of the oil.

Graph 5 illustrated the effect of the following three sets of conditions :—

Curve (i.) Liquor very strongly alkaline.
" (ii.) Weakly alkaline.
" (iii.) Free alkali less than equivalent to total possible acidic products.

At the point (A) there occurs a very rapid absorption of available chlorine until the sulphur compound is entirely removed. This condition is always avoided on a plant scale.

Sulphuretted hydrogen.—This is oxidised partly to free sulphur (which dissolves in the oil) and partly to sulphuric acid.

Free sulphur is unattacked by hypochlorite, and is a very undesirable constituent of motor spirit. The hydrogen sulphide therefore must be removed before bleach treatment, and this is effected by soda which is, moreover, a cheaper refining agent for removing this impurity.

Thiophene.—This type of compound is unattacked by hypochlorite.

During bleach treatment even with very alkaline liquor, a small amount of chlorination may take place.

So far, isolation and identification of the compounds has not been achieved, but work on the hydrolysed products of the acidic bodies leads to the supposition that they are derived from mercaptan of the type $R.SO_2Cl$. The evidence for these deductions will be dealt with later in this article.

The removal of these compounds from the oil is essential, otherwise they tend to decompose and form corrosive products. This problem was always a stumbling block to early investigators of the hypochlorite process, and resulted in patents being taken out incorporating the use of metallic basic salts, etc., for this purpose, none of which, however, could have effected this object. A successful method, however, has since been developed.

Manufacture of Solutions of Hypochlorite.

Sodium hypochlorite.—This was used generally at one time and was manufactured both by electrolysis of a solution of brine with carbon electrodes or by bubbling chlorine into 10 per cent. soda solution. The particular method employed at any one refinery depended on the economic considerations.

Where chlorine was easily procurable and cheap the second method was used.

By chlorination of 10 per cent. soda, a bi-normal liquor is produced. The alkalinity is controlled to be in the neighbourhood of 0·4 gms. caustic soda per litre, so that one dilution to 0·34N (working strength) the soda content would be between 0·5 and 1·0 gms. per litre. Bleach liquor manufactured by the electrolysis of brine, could not be made stronger than 0·34N with the plant installed, but the alkalinity maintained falls approximately between the above limits. Subsequently, calcium hypochlorite was adopted as a refining agent on grounds of economy.

At the Anglo-Persian Oil Company's refinery at Swansea it is manufactured by chlorinating milk of lime liquor. The product is about 2N in strength and is saturated with lime (approximate solubility 1·3 lb. lime per 100 gallons or 1·3 gram per litre).

This liquor, if free from suspended lime, gives on dilution to 0·34N an alkali content of about 0·2 gms. lime per litre, but usually a carry forward of suspended lime is present which dissolves on dilution, maintaining the maximum alkalinity. At Abadan, Persia, liquid chlorine is not available, and bleaching powder is used for making up the liquor. The process is necessarily more expensive.

The exact working strength and alkalinity of the bleach liquor used for large scale washing has changed somewhat with the change in washing equipment. In the early days all washing was carried out on the batch principle. The bleach liquor was drawn from the bottom of the washer and sprayed overhead through the spirit. The process was rapid up to a point, but with the very rigorous degree of refining maintained at the time, the last stages of treatment were very slow, and it was usual to de-stabilise the bleach liquor by the addition of metallic salts, sulphuric acid, or by bubbling flue gases into the washer, whereby the coupon dioxide throws out carbonate.

This de-stabilisation had the undesirable effect of causing chlorination.

Also, for the latter reason, bleach liquor stronger than 0·34N could not be used for washing purposes.

The treatment was necessarily heavy enough to ensure that after subsequent distillation, the spirit fraction would be up to specification without having to be given an additional bleach treatment. The sulphur content of the spirit was about 0·015 per cent. This entails using approximately 3·5 grams of chlorine per litre of once-run-distillate, during which process the kerosine fraction was automatically partially refined.

At this stage four washers used for intermittent washing were linked up and used for continuous washing, one for soda washing, one for water washing and two for bleach washing.

Soon after this unit was commissioned, as a result of considerable experimental work, a process was worked out and successfully applied on the large scale continuous plant.

With the pump agitation method of continuous washing, the time of contact of spirit and chemical is less than 30 seconds.

Increased contact was achieved by producing an emulsion of soda and spirit by the addition of hypochlorite liquor. This caused the precipitation of calcium hydroxide which acted as the emulsifying agent. To commence with, 20 per cent. soda solution was

used, and two or three gallons of 0·34N bleach liquor were added per 2000 gallons of soda solution.

An emulsion was produced in the pump that lasted for anything up to several hours, but it was essential to break this emulsion after a specified time, however, in order that soda should not be carried over. It was found that this could be achieved rapidly and efficiently by passing the emulsion into 20 per cent. soda solution (the spirit being the disperse phase).

Accordingly, the emulsion, when made, was passed into an emulsion washer, where it remained slowly passing through from bottom to top.

After this period of standing, the emulsion was delivered back into the washer containing the soda used for emulsification. The delivery pipe passed overhead and was led under the running soda level. In this way the emulsion was broken, and when using 20 per cent. soda solution, to which bleach liquor had been added, the process worked very well for days, but eventually the emulsion became so viscous that it was almost unpourable. The breaking process was rendered much more difficult and very often resulted in considerable carry over losses, due to the sodium sulphonates formed. These salts are good emulsifying agents and so produced an enhanced effect. To overcome this trouble the soda strength was dropped to between 10 and 15 per cent. in strength when the difficulty disappeared. It is not possible to work below 10 per cent. soda as the emulsion is not permanent enough. Make-up soda of 20 per cent. strength is used and discarded when 10 per cent. in strength. In this way double the soda is used to the amount consumed, but the returned soda is used up on other refining processes. The soda used in this process is 3 lb. per ton of spirit washed, and of this 50 per cent. or 1·5 lb. per ton are returned to use elsewhere. As a result of these achievements the refining process was considerably modified.

The hypochlorite treatment was transferred from the naphtha stage to the benzine stage. Soda washing treatment only was given to the former, which was redistilled and then bleach washed. As a direct result the hypochlorite was reduced to 3 gms. per litre of spirit or 2·1 gms. per litre on the O.R.D. as compared with 3·5 gms. previously, showing considerable economies.

By this change of process certain modifications had to be made at the hypochlorite treatment stages. It was found to be rather more difficult to maintain a specification finished spirit with the bleach liquor alkalinity at about 1·2 gms. CaO per litre.

Accordingly the alkalinity had to be reduced, and this was achieved by adding sulphuric acid to the bleach liquor until the alkalinity was about 0·4 gms. of lime per litre. Great care had to

be exercised to avoid going below 0·3 gms. per litre, otherwise the acid products of oxidation would more than neutralise the alkalinity and so render the liquor acidic, causing excessive chlorination.

With the advent of better settling of the strong bleach liquor it was found that the dilute liquor had slightly too low an alkalinity. Better results are obtained by a more alkaline liquor from the point of view of dechlorinating, and the bleach liquor now used has an alkalinity between the limits of 0·9 gms. and 1·1 gms. of lime per litre. This is produced by the addition of alkali to the dilute liquor.

Spirit now refined is straight run benzine—*i.e.*, cut directly from the crude oil. After soda washing it has a sulphur content of 0·065 per cent. and a mercaptan content of 0·05 per cent. It is refined to a doctor-free state (S=0·04 to 0·043 per cent.) by 1·5 gms. of chlorine per litre, and to give a product having a sulphur content of 0·03 per cent. by 2 gms. per litre.

From these figures a rough average conversion to disulphides and sulphonic acids can be evaluated, assuming that no sulphides are present, an assumption which is probably not far from the truth.

The mercaptan content of the spirit before hypo treatment is 0·05 per cent. After 1·5 gms. chlorine per litre these have all been oxidised to either disulphides or sulphonic acids (as the spirit is doctor free).

One atom of chlorine per atom of sulphur has been consumed on all the 0·05 per cent. In addition, to convert disulphide sulphur to sulphonic acids a further 5 atoms of chlorine per atom of sulphur are demanded. This can be expressed algebraically as follows:—

To convert mercaptan sulphur to disulphides will take the following consumption of chlorine per litre of spirit:

$$\frac{0{\cdot}05 \times 7{\cdot}2 \times 35{\cdot}5}{32} \text{ gms. chlorine} = 0{\cdot}5 \text{ gms./litre.}$$

To convert to sulphonic acids on x per cent. of sulphur will take:

$$\frac{x \times 7{\cdot}2 \times 5 \times 35{\cdot}5}{32} \text{ gms. chlorine} = 40 \text{ gms./litre.}$$

As the consumption to the doctor free state is 1·5 gms./litre, we have:

$$0{\cdot}4 + 40x = 1{\cdot}5$$

Whence $x = 0{\cdot}027\%$

This means a reduction of total sulphur content from 0·065 per cent. to 0·038 per cent. which agrees with works practice.

The extra treatment necessary has to reduce the sulphur from 0·038 to 0·03 per cent. This will take

$$\frac{0{\cdot}08 \times 7{\cdot}2 \times 6 \times 35{\cdot}5}{32} \text{ gms. chlorine/litre of spirit or } 0{\cdot}4 \text{ gms.}$$

per litre, which brings the total bleach consumption to 1·5 + 0·4 or 1·9 gms./litre.

Actually the treatment required is between 1·9 and 2 gms. per litre, a very small discrepancy.

The time of contact between bleach and spirit in above cited cases was the same, and so the foregoing figures give a very fair idea of the comparative reactivity on a large plant scale of calcium hypochlorite with various alkalinities, in contra-distinction to the laboratory work carried out on sodium hypochlorite by Birch and Norris referred to earlier in this paper.

Subsequently to this method of pump agitation washing, a mechanically agitated washing unit has been installed.

This has not affected the hypochlorite washing process, but on account of the comparatively long time of contact between spirit and washing liquor it has been possible to discard the emulsion process for removing acidity.

A weaker alkali solution can be used (around 8 per cent.) quite well. This does not emulsify, and the consumption of soda has been appreciably reduced. Carry-over soda losses are practically nil. The actual consumption is around 1 lb. of soda per ton of spirit, the theoretical figure being $\frac{1}{4}$ lb. per ton, whereas with the emulsion process the consumption is $1\frac{1}{2}$ lb. of soda per ton of spirit.

Plumbite Treatment.

It has been summarily dealt with in the "Introduction," and with certain oils is possibly an economic rival to the hypochlorite process where the latter is comparatively expensive on account of local conditions.

The drawback of this process is that practically very little sulphur is removed by treatment.

Theoretically none is removed, as will be seen by the following equation, which represents the reaction between mercaptans, plumbite and sulphur:

$$\begin{matrix} R\text{—}S\text{—}H \\ \\ R\text{—}S\text{—}H \\ R\text{—}S \\ \quad 1 \\ R\text{—}S \end{matrix} + Pb\,O \quad \begin{matrix} R\text{—}S \\ \quad 1 \\ R\text{—}S \\ R\text{—}S \\ \quad 1 \\ R\text{—}S \end{matrix} \quad Pb + H_2O$$

$$Pb + S \quad + \quad PbS$$

The litharge is converted into lead sulphide by the addition of flowers of sulphur *via* the intermediary stage of lead sulphide,

and the sulphur removed as lead sulphide is equal to the elemental sulphur added during the treatment.

Actually, lead sulphide acts slightly as an adsorbing agent and removes a small quantity of sulphur by virtue of this fact.

Conversion from mercaptans to disulphides raises the boiling point from 60° C. to 120° C., and on re-distillation the latter compounds tend to be left in the residue by virtue of this increase in boiling point.

The re-distillation is a necessary feature of the process where oils of high sulphur content have to be contended with, but the reduction of sulphur is not very great. The odour of the re-distilled oil is materially improved, but although it is doctor negative, a small wash of plumbite solution greatly enhances the finished product.

As an example of results of this treatment the following figures may be quoted. Straight run benzine, after removal of hydrogen sulphide, has a sulphur content of 0·075 per cent. After plumbite washing to make doctor negative, and re-distillation, the sulphur content is only reduced to 0·045 per cent. This is high compared with hypo refined oils, but the final product is sweet and marketable.

Considering another type of straight run benzine, the sulphur content of the hydrogen sulphide free oil is 0·22 per cent., and after soda washing it is 0·14 per cent. This oil, after plumbite treatment and re-distillation, is only reduced to a 0·10 per cent. sulphur content. Although not of a bad odour it would be unmarketable, and the plumbite process, however economical, would be inapplicable.

The economical side of the process depends purely and simply on the cost of recovery of the lead sulphide.

This can be effected cheaply where spent acid is available, the interaction forming lead sulphate which on boiling with caustic soda regenerates the plumbite.

It is claimed by certain investigators that by air blowing plumbite solution with spirits containing mercaptans, the conversion to disulphide takes place with recovery of the plumbite in situ, whereby only 1/10th the theoretical quantity of plumbite is required for the treatment.

If this be true, plumbite treatment would be substantially cheaper.

This process has been investigated from the point of view of removing elemental sulphur only; for, with an oil containing a comparatively high amount of this element, a small quantity of plumbite which will throw out sufficient lead mercaptide to react in equivalent proportions with the sulphur present should suffice to remove all the latter. Actually a rapid reduction takes place down to 0·0008 per cent., but below this the reaction between

lead mercaptide and sulphur is too slow, and this figure is about the minimum obtainable.

Where large quantities of elemental sulphur are present this method is recommended, but for very low figures where sodium sulphide is available the latter reagent is recommended, which, as explained earlier in this article, will reduce the elemental sulphur content to 0·0002 per cent. moderately easily.

Sulphuric Acid.

This reagent is used largely in America. It has the drawback of presenting a difficulty in the means of disposal of the acid tar. Furthermore, it tends to remove valuable aromatic compounds from the oil.

The process is simple and is usually carried out continuously, the acid being injected into the stream of benzine, afterwards passing through settlers, and water and alkali washing and settling stages. With the same straight run benzine ½ per cent. of F.O.V. is sufficient to produce a doctor negative oil having a sulphur content of 0·035 per cent.

It is uneconomical to recover the acid, merely for the sake of the acid, but many recovery processes are employed to avoid disposal of the acid tar.

Sulphuric acid is also used for refining products such as kerosine, white spirit and lubricating oils. Kerosine of high colour and sulphur content about 0·20 per cent. is reduced with ½ per cent. F.O.V. to nearly a water white oil having a sulphur content of 0·12 to 0·13 per cent. A small bauxite treatment of about 1 lb. per gallon following this suffices to give a water white oil having a sulphur content below 0·10 per cent.

Sulphur Dioxide Treatment.

As explained in the introduction, this reagent acts purely by virtue of its solvent action on aromatic, unsaturated and sulphur compounds.

The treatment is 100 per cent. by volume, and the losses of sulphur dioxide are only of the order of 0·1 per cent. by volume on the liquid sulphur dioxide handled per cycle.

Liquid sulphur dioxide is used chiefly for kerosine refining. It is too expensive a treatment to give to motor spirit, and, moreover, would impair the efficiency of the engine test of the spirit by reducing the H.U.C.R. by virtue of the aromatic compounds removed. Furthermore, it is not a complete refining agent on its own, as all compounds affected by liquid sulphur dioxide only

partition themselves between the latter and the oil. A finishing treatment with some other reagent to remove the remaining mercaptan compounds would be necessary.

A typical result of a treatment of 100 per cent. sulphur dioxide on straight run kerosine from Persian crude is as follows:—

	Before treatment.	After treatment.	Extract oil.
Sp. gr. @ 60° F. ..	0·8000	0·7875	0·870
Mercaptan sulphur, per cent.	0·038	0·027	0·083
Total sulphur, per cent.	0·22	0·07	0·76
Flash-point	115° F.	125° F.	—

The removal of aromatics produces an excellent burning oil, having a non-smoky flame.

The sulphur dioxide refined oil has to be further treated to remove remaining mercaptans and the last traces of colour.

Bauxite Treatment.

This treatment, which depends on the property of anhydrous bauxite of removing sulphur compounds and colour, is fairly expensive owing to the losses in treatment, and although quite capable of producing a refined benzine from soda washed benzine is out of the question on "costs" grounds.

Nevertheless, as a refining agent for kerosine it has been in use for many years.

The *modus operandi* has been detailed in the introduction. On a plant scale, trouble is experienced in maintaining a balance between the various degrees of refining required.

A marketable oil has to be doctor negative, have a sulphur content of 0·10 per cent. or less, and a water white colour.

Unrefined straight run kerosine has a colour of approximately 4 yellow in an 18 in. cell (Lovibond Scale), a sulphur content between 0·14 per cent. and 0·20 per cent., according to the cut, and a mercaptan content between 0·035 per cent. and 0·045 per cent. About 3 lb. of bauxite per gallon of kerosine treated suffices to reduce the colour to water white (2·3 yellow in an 18 in. Lovibond cell). To reduce the sulphur content to 0·10 per cent. requires 3½ lb. per gallon treatment. A mercaptan content of 0·045 per cent. requires a much heavier treatment, however, as this type of compound has to be removed to a mere trace. In order to obviate an increased treatment to satisfy this requirement, a bleach treatment between 0·6 grams and 0·8 grams of chlorine per litre is given to the soda

washed straight run kerosine. This reduces the mercaptan content to between 0·02 per cent. and 0·025 per cent., after which a bauxite treatment of 3 lb. to 3½ lb. per gallon is sufficient to give a doctor negative oil.

Straight run kerosine of 0·800 gravity, cut straight from the bubble cap trays of a fractionating column, has a sulphur content below 0·22 per cent., a mercaptan content of approximately 0·04 per cent., and is water white in colour. After sulphur dioxide treatment it has a sulphur content of 0·07 per cent.—0·08 per cent., a mercaptan content of 0·025 per cent., and is still water white.

Apart from being doctor positive, it is a well refined oil and would require no further treatment. To make it doctor negative is essential, however and would necessitate a bauxite treatment about 1½ lb. per gallon. This is uneconomical as a small bleach treatment will render the oil doctor negative, and costs very little compared with the filtration and its consequent oil losses.

REVIEWS.

Earth Flexures. H. G. Busk. Pp. viii. + 106, 96 Figs. University Press, Cambridge. 12s. 6d. net.

Many years ago a geologist of world-wide repute made the remark: "Thank heaven geology can never become an exact science." The last two decades must have seriously shaken his beliefs. Geophysics has come to stay with its abstruse formulæ and intricate diagrams, though the geologist still holds the master cards when it comes to interpretation of results.

Now, however, comes a volume on the mathematical treatment of geological problems from the ranks of the geologists themselves, and Mr. Busk in the preface to "Earth Flexures" suggests that if necessary his brother geologists should refresh their memories with Smith's "Geometrical Confes."

Chapters I. and II. are confined to introductory matter and a general description of sedimentation and folding.

In Chapters III. and IV. Mr. Busk really gets to grips with his subject in the form of "Propositions" devoted to geometrical constructions of underground structures from surface data, ending up with "Prop. 21: In any competent fold the conics with which the axial plane is constructed are successively tangential to one another."

Then follows a chapter on "Geological Mapping for Accurate Section Drawing," giving many useful hints, obviously based on the author's wide personal experience

Chapter VI., which may be said to form the practical proof of the first part of the book, deals with "The flexures of Tertiary age in the Petroliferous rocks of some extra-European countries." Tectonic problems in Burmah, Persia and Sinai are dealt with both geologically and geometrically, the author showing that his geometrical methods have been borne out by the results of drilling. This chapter is profusely illustrated by maps, sections and block diagrams.

Admitting that the representation of a geological map in black and white is at all times a difficult matter, we feel that the author has not done himself justice, with the notable exception of Fig. 84, which is a model of clearness. The block diagrams, though certainly illustrating what is required, are somewhat crude in their detail.

To return, however, to Chapters III. and IV., the author must be congratulated on his treatment of the geometry of folding which puts section drawing on a scientific instead of a free hand basis, but he has put in the hands of the geologist a weapon which must be used with extreme caution. The question must arise in every case whether the surface data are sufficiently accurate to admit of such mathematical treatment, and whether at depth variations in the strata and changes in the direction of pressure may not introduce such variable factors as largely to upset the geometrical solutions. Mr. Busk has confined himself to areas which are noted for their richness in surface data, and in certain cases for their approximation to theoretical structures, but a word of warning must be sounded lest the geologist having determined his surface data forsakes the inexact science of geology for the exact science of geometry. In other words, Mr. Busk's book will be of great value to the experienced geologist who can determine when and how to apply the constructions given, but may equally be a source of danger to the less experienced man who may get the impression that, having determined his surface dips and strikes, the rest follows geometrically.

James Romanes.

LES RICHESSES MINIÈRES DE LA NOUVELLE ROUMANIE. Aurel P. Iancoulesco. Paris: J. Gamber, 1928.

In a volume which attempts to deal with the mineral resources of a large country like Rumania, the subjects dealt with are so diverse that if the balance is to be retained the treatment must necessarily become statistical and descriptive matter be reduced to a minimum. The author has distributed his attention very fairly among the mineral resources in their order of importance, and petroleum, which ranks as the most important mineral asset of the country, gets the greater share of his attention.

After a brief chapter on the people who inhabit the extended boundaries of modern Rumania, a chapter which leaves us wondering what genius could weld into one whole so many diverse and antagonistic elements, we are hurried through to a brief and inadequate account of the geology and drilling sides of the subject, which add no value to the book nor do they appear to be necessary to a reader who is, by his interest in such a subject, almost bound to be conversant with the broader principles. Some useful information is given with regard to the production side of the industry, the companies concerned in the work and the statistics of their individual stake in the industry. The most interesting portion of the book, however, is that which deals with the post-war readjustments and the incidence of the new mining laws on an industry which was struggling to regain its foothold after the severe blows of the world war, the destruction of wells and equipment to prevent them from falling into hostile hands, and the unsettled political conditions of which Rumania inherited more than her share.

The assumption of control by the State of the Under-Surface rights in the Law of 1924 and the restrictive measures which were introduced in the working of the petroleum industry were intended specifically to reserve for the State and for Rumanians a large share of interest in the resources of the country. Some of the guiding principles which underlay this legislation are detailed by the author in the last section of the book, and are upheld in principle as a logical attempt to conserve the energy of the country and prevent wasteful exploitation by foreign capital with little benefit to the country itself.

An impartial observer would undoubtedly agree with many of these conceptions, but it is doubtful whether in fact many of the reactions have tended to the benefit of the country, and in one particular, the need of capital, it was obvious that such restrictive influences would restrain post-war activity and fail to attract the capital necessary for development. Yet in spite of this the industry has grown and forged ahead of its pre-war production with the increased efficiency of modern methods of exploitation.

Some of the methods introduced to foster home industries do not appear to have been altogether justified. The author cites as an instance the attempt to develop a metallurgical industry in a country largely devoid of iron ores by restrictive tariffs on imports, an attempt which produced a disproportional loss to the country by the increased cost of machinery to the users.

Natural gas, salt, coal, lignite, gold, silver, copper and iron are all given separate treatment in the third section of the book. The writer is sometimes disposed to give more than due credence to optimistic reports of large reserves of available minerals. Thus, for instance, mica is described to be exceedingly abundant and of excellent quality on what is the scantiest of evidence. In spite of this tendency he has succeeded in giving to his readers an excellent summary of the resources of the country, and his observations on the political aspect of the subject, the attempt of the State to develop and yet conserve the resources, have an even wider application than to Rumania.

V. C. ILLING.

STRUCTURE OF TYPICAL AMERICAN OILFIELDS. Vol. I. American Association of Petroleum Geologists. London: Thomas Murby and Co. 1929. Pp. xvii.+510.

This volume contains a description of 30 U.S.A. oilfields situated in 13 States, the greater number of them being in Texas, Oklahoma and Kansas. Each of the descriptions has been written in a nearly uniform pattern, so far as the individual characteristics permit, by an expert who knows the field.

The prefatory note states that: "These volumes are designed to afford authoritative and modern descriptions of typical oilfields in the United States," and this conveys an accurate account of the book, for the description of the fields have set a standard which will be hard to beat.

The general description is as follows: Introduction; Topography and Drainage; Geology: General and Special, Surface and Underground; Structure; Oil Sands; Water; Production and Production Methods; Future of the Fields; though for various reasons not all of these items are dealt with in every field.

The book is very well illustrated by maps and sections, and one is compelled to speculate as to whether some of the kinks in the underground contour lines are not due to crooked holes.

The information collected here will be of real value for reference purposes for experienced men, and at the same time form an interesting study for beginners.

T. R. H. GARRETT.

CHEMICAL ENGINEERING AND CHEMICAL CATALOGUE. Edited by D. M Newitt. 5th Edition. Pp. 401. London: Leonard Hill, Ltd. 15s.

Those who have to deal with chemicals and chemical plant will find the fifth annual edition of this reference catalogue possibly of greater value than its preceding issues. The index to suppliers has been completely revised and largely added to, and the section dealing with Data and Tables has been doubled, many of the Tables having been specially compiled for the Catalogue. In the present volume, the division of the various sections is indicated by thumb indentations, an improvement on the previous system of protruding tabs.

GEORGE SELL.

BOOKS RECEIVED.

MARINE OIL ENGINES. Sterry B. Freeman. Diesel Engine Users' Association. 7s.

This paper, which was read before the Diesel Engine Users' Association on October 12th, 1928, discusses the application of the Diesel engine to marine work, and is published in full, together with a report of the discussion which followed.

DESCRIPTION OF THE COALFIELDS OF NORTH STAFFORDSHIRE. Dept. of Scientific and Industrial Research. London: H.M. Stationery Office. Pp. vi.+14, with a sketch map. 1s. net. Postage extra.

This is the fourteenth report of the series on the Physical and Chemical Survey of the National Coal Resources, and deals with the geology of the coal seams of the North Staffordshire area.

THE ASSAY OF COAL FOR CARBONISATION PURPOSES. Part II. Dept. of Scientific and Industrial Research. London: H.M. Stationery Office. Pp. vi.+34, with 5 Figs. and 2 Plates. 1s. net. Postage extra.

The Fuel Research Technical Paper, No. 21, is a continuation of No. 1 of the same series, and gives results of over seven years' use of the apparatus described in the previous work, the Gray-King Assay Apparatus. A larger scale apparatus is also described.

LABORATORY CORROSION TESTS OF MILD STEEL WITH SPECIAL REFERENCE TO SHIP PLATE. Henry S. Rawdon. U.S. Bureau of Standards Research Paper No. 42. U.S. Government Printing Office, Washington, D.C. 5 cents.

A series of corrosion tests on mild steel plates, of varying copper content, were carried out and the results are given.

APPARATUS AND METHODS FOR THE SEPARATION, IDENTIFICATION AND DETERMINATION OF THE CHEMICAL CONSTITUENTS OF PETROLEUM. E. W. Washburn, J. H. Bruun and M. M. Hicks. U.S. Bureau of Mines Research Paper No. 45. U.S. Government Printing Office, Washington, D.C. 10 cents.

The following methods and apparatus are described: a rectifying still with 20-plate column and means for controlling and measuring the plate temperatures; an all-glass rectifying still for vacuum distillation; various types of molecular stills; fractionation by crystallisation or melting, and apparatus for combustion analysis in which all rubber connections are eliminated.

THE PRICE OF PETROL. E. H. Davenport. London: General Press. 1s. net.

A VAPOUR-PRESSURE CHART FOR HYDROCARBONS. Hal B. Coats and George G. Brown. University of Michigan Circular No. 2.

ERRATA.

Owing to Mr. G. Heseldin's absence from England he was unable to correct his reply to the discussion on his paper, "Drilling and Production Methods in the Greater Seminole Field, Oklahoma, U.S.A., which appeared in the December, 1928, issue of the Journal. He now informs us that the following corrections should be made :—

Page 821.—Line 31.—Should read "only two wells to every 40-acre lease, compared with the usual."
Line 32.—For "out of" read "to."
Line 34.—For "to 40 wells" read "for a 40-acre lease."
Line 43.—For "wild" read "wide open."
Line 46.—For "wells" read "acres."
Page 823.—Line 8.—For "put on" read "taken off."
Line 16.—For "in the adjoining well" read "on the adjoining lease."
Line 17.—For "on a swabbed well" read "on a certain swabbed well that came before his notice."
Line 19.—For "the pumps" read "the slush pumps."
Line 25.—For "recirculating" read "recirculated."
Line 26.—Delete "true."
Line 40.—For "and some wells were reducing" read "and on some wells it had reduced."